Psychological Monographs

An Experimental Evaluation of Jost's Laws

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NEW YORK CITY

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ACKNOWLEDGMENTS

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CHAPTER I

INTRODUCTION

ONE of the several early attempts to express constant relationships in the field of learning was Jost's law. In 1895 Jost undertook to check the findings of Ebbinghaus (8) on the efficacy of the distribution of repetitions for later retention. At the conclusion of nine brief experiments Jost formulated two laws:

FIRST LAW: "Given two associations of the same strength, but of different ages, the older one has greater value on a new repetition."

SECOND LAW: "Given two associations of the same strength, but of different ages, the older falls off less rapidly in a given length of time." (20, *p. 472.*)

These laws contain a number of assumptions which can best be revealed by an examination of the experimental basis for the laws and the logic of their derivation.

Experimental Basis for Jost's Laws. Jost confirmed Ebbinghaus's finding of a greater advantage in relearning when the learning repetitions were distributed over several days than when they were massed in a single session. To arrive at this result Jost used two subjects and considered his results as two of the nine experiments. Müller and Schumann (33) had pointed out the possibility that Ebbinghaus's (8) results were, in part, due to the greater fatigue developed in the course of learning the mnemonic material by massed repetitions. Consequently, as his third experiment, Jost arranged especially long sessions in which massed learning of some lists of nonsense-syllables alternated with a comparable number of repetitions of the distributed series. Thus, the fatigue, which presumably was most operative later in these long sessions, affected the same number of repetitions in the massed as in the distributed learning. In his results the advantage of the distributed practice was still evident, though somewhat reduced. Jost then varied the amount of distribution and conducted three more experiments (three subjects) in an effort to determine some limit at which distribution of practice was no more effective than massing. No such limit appeared.

At this point Jost concluded that age was the active force which was making the distributed learning superior to the massed, and that age operated by actually producing different degrees of learning in the compared series which had had the same number of repetitions. In order to check his assumption, Jost added three more experiments in which the compared associations were given different degrees of learning and then tested at various intervals for retention. In these investigations he found no limit to his generalization that the older habit is of more value on a new repetition. Consequently, Jost considered his laws sufficiently general to include the two situations: (1) when one series of associations is older than the other because of distributed rather than massed repetitions, and (2) when the older has been learned to a higher degree and then forgotten to a point corresponding to the younger associations.

In addition to these assumptions both of Jost's laws contain a certain paradoxical element. How can two associations have the same strength and yet reveal unequal power on immediate relearning or subsequent retention? Jost actually referred here to an equal amount of the learned material that could be recalled at a given time. He summarizes his meaning in semi-practical terms as follows:

". . . dass wir hier zwei voneinander durchaus verschiedene Bethätigungs-weisen des Gedachtnisses kennen gelernt haben. Man kann, wie wir gesehen haben, von einem bestimmten Stoffe relativ sehr viel noch wissen, aber trotzdem noch ziemlich viel Wiederholungen brauchen, bis man denselben wieder vollständig eingeprägt hat. Andererseits giebt es Fälle, in welchen wir von irgend einer Sache nur noch sehr wenig wissen, dessen ungeachtet aber eine bedeutend kürzere Zeit zur Wiedererlernung nötig haben als im ersten Falle." (20, *p. 463*.)

In no case did Jost achieve equality in his compared younger-and-older associations, but the differences were in the direction to justify the conclusions he drew.

These laws have an accredited place in the body of psychological knowledge, but the basis for their acceptance lies in the often seen superiority of distributed over massed practice in learning,[1] and in the theoretical uniformity of retention curves rather than in Jost's nine brief experiments. It is apparent that his experiments possess the inadequacies of the early studies of memory and learning. He used only one subject for an experiment; he presented several lists to his subjects each day; he served as a subject for his own research; and, of course, he had no measure of the

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[1] The forty principal studies, confirming the superiority of distributed over massed practice, have been listed by McGeoch (27, *pp. 16-18*). An analysis of the factors influencing relative economy of massed and distributed learning was made by Ruch (42). These works do not, of course, include the more recent experimental work of Hovland (14) or the theoretical interpretation of Hull and associates (15 and 17).

reliability of his findings. That Jost was able to formulate his laws at all is evidence of the uniformity of results in this field of investigation.

Jost's Assumptions in Light of Current Theory. Not only have Jost's experimental methods been superseded but the basic assumption involved in his laws is today untenable. Age is no longer regarded as an active process, but solely as a frame of reference. There is current need for a demonstration of the process operative in time and a restatement of Jost's laws in the light of these findings. Recent studies by Hull (16) and Hovland (14), designed to test the value of conditioned response principles in the field of rote learning, suggest that the dissipation of secondary inhibition,[2] which is built up particularly in the middle of a list during learning, is the active process which is correlated with age. Hovland (14) has shown that Ward's reminiscence effect (45) at short intervals of time is probably due to this, since it is much reduced by the device of distributing the repetitions in learning. These current findings not only suggest the active process which may be operative in Jost's laws but they reveal (45) a reliable exception to the theoretically uniform retention curves. Doubt is thus cast on the generality of Jost's second law.

In spite of the present inadequacy of the experimental basis of Jost's laws and the assumptions involved in them, almost no experimental attack has resulted. There are two relatively recent studies which deal directly with Jost's laws. Britt and Bunch (4) had an older maze habit relearned to the standard criterion just before the comparison trials with the younger habit. The study was essentially designed to determine which habit, the older or the younger, was most subject to retroactive inhibition from training on an interpolated third maze. The authors conclude that the older is less subject to retroactive inhibition. In the control groups they find evidence for the confirmation of Jost's law. By this method, of course, the strength of the older is much increased by the immediate relearning before the comparison trials and so no possible limits to Jost's law can be approached. In a similar manner Britt (3) found that the older habit shows greater transfer to a new habit than a younger one. In neither of these studies are the assumptions underlying Jost's laws examined.

Purpose of the Present Study. A comprehensive analysis of Jost's laws would involve much more than can be accomplished in a single study. It

[2] Hull's interpretation of rote-learning according to conditioned reaction principles (15), posits the dual processes of excitation and inhibition. Wendt (46) and Guthrie (12) on the other hand, find in conditioning a single process, excitation. In the present study inhibition is used with psychological rather than physiological connotations. In the case of the learning of a rote series the inhibitory factor probably is competitive interference due to remote backward and forward associations.

would demand obtaining comparable associations [3] (preferably more than a pair of equivalent associations) which had had various amounts of distribution in learning and were now, by some convenient criterion, equal. Relearning and subsequent retention should be compared for these associations together with error distributions and other functional characteristics indicative of their essential similarities and differences. Likewise, it would demand the comparison of other equated associations which had previously been learned to different criteria but had been forgotten to a single criterial level. The functional characteristics for these associations would then be determined in order to reveal, as far as possible, the essential differences. Finally, a comparison between the results on distribution and the results on different degrees of original learning would show to what extent Jost was justified in subsuming all of this material under a single pair of laws. By the same comparison it would be possible to infer the active process, which under some circumstances may not even be closely correlated with time, but which Jost referred to as age. Such a study would clarify the present laws in addition to revealing the more basic assumptions.

As stated by Jost, the first law has limited scope. He states, " given two associations of the same strength but different ages, the older has greater value on *a* new repetition ". Literally this would mean that the older habit profits more on a single relearning presentation. It has customarily been expanded to mean that the older association, or habit, has greater value on further repetitions. It is not beyond possibility that the literal statement may be a more adequate description than the expanded form.

The present investigation was designed as an initial attack on the problems outlined above. Jost's laws were investigated only as they apply to associations which have received various amounts of original learning and have been forgotten to levels of equivalence with younger associations. On the basis of this material the purpose was: (1) to check the validity of Jost's laws as he stated them and to obtain, if possible, a mathematical statement of the relationship between the older and younger habits; (2) to determine how justified is the customary expansion of the first law; (3) to establish, if possible, some limits to Jost's laws; (4) to examine the functional equivalence in the older and younger habits with the view to defining the active process operative with age.

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[3] " Associations " is used here and elsewhere in the study in a broad sense. Possible alternate definitions would be series of associations, habit, series of habits, excitatory tendencies and sequential excitatory tendencies. This discord in terminology is only justified by an assumption of essential agreement in the experimental results no matter which specific learning function is studied. " Associations " is not used here to indicate individual associative bonds.

CHAPTER II

THEORETICALLY, Jost's laws apply to the memorization of all sorts of materials and the learning of all habits. However, nonsense-syllable learning was chosen for the present study because it is possible with this technique to obtain data for a number of checks of Jost's law in the available time. In addition the well-controlled results of Ward (45) and Luh (23) suggest the degrees of partial learning to use in order to obtain the comparable points for later analysis of Jost's laws.

Previous Studies of Retention Following Partial Learning. Ebbinghaus (8) conducted the first study of retention following partial learning in his investigation of retention as a function of number of repetitions. He learned 16-unit nonsense-syllable lists and varied systematically the number of initial repetitions from 8 to 64. Retention was tested after an interval of 24 hours. Luh (23), in checking Ebbinghaus's results, proceeded somewhat differently to employ four degrees of learning, 100 per cent, 150 per cent, 67 per cent, and 33 per cent, of 12-unit nonsense-syllable lists. The average number of presentations for "complete mastery" were determined for his ten subjects on the basis of twenty preliminary series. Then the number of presentations was decreased or increased according to a percentage of this average score. In every case retention curves were plotted after intervals of 2, 3, 4, 6 and 12 hours, 1 day and 2 days. Unfortunately, Luh's purpose was to see whether Ballard's reminiscence (1) could be attributed to method of recall or to degree of learning, so recall during this part of his study was tested only for written reproduction, recognition and reconstruction. In every case Luh obtained uniform retention curves of the classical Ebbinghaus type. The curves were negatively accelerated. Retention decreased with time and the forgetting was more rapid at first.

In another section of his study, Luh demonstrated that the anticipation method in learning, recall and relearning produced a lower degree of learning and more rapid forgetting than any other method. Thus, the greater part of forgetting could be included in the space of 24 hours. Ward (45) conducted his study of retention following short intervals of time by Luh's anticipation method. His criteria of learning were 1 errorless anticipation of a 12-unit nonsense-syllable list, 7 correct anticipations on 1 trial, and a single presentation of the list. His results indicate two

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possible limits to the classical retention curve. He demonstrated the
increase in retention following a lapse of time, reminiscence; and he
obtained a practically level retention curve at his lowest degree of learning.
Ward cited Melton (29), and pointed out the excessive variability at this
low degree of learning. Accordingly, little reliance can be placed in the
leveling tendency of this retention curve.

Experimental Method and Subjects. In the present study it was desirable
to obtain greater stability in the retention curve after a fairly low degree of
learning. In an attempt to achieve this, an average criterion for low
degrees of learning was introduced. It was thought that this would reduce
certain irregular spurts in the learning process. In nearly every other
respect the methods of Ward and Luh were followed. Subjects memorized
12-unit nonsense-syllable lists by the spelling-anticipation method to three
different degrees of learning. The lists were relearned to 12 correct antici-
pations on a single trial after various intervals of time following the learn-
ing. Thus, the highest degree of learning, which we shall designate as
Learning I, was learned to the criterion of 12 correct anticipations on a
single trial and relearning was done after intervals of 6 seconds (immediate
relearning), 10 minutes, 20 minutes, 40 minutes, 60 minutes, 2 hours, and
24 hours. Learning II proceeded until the criterion of an average of 7
correct anticipations on two successive trials was reached and relearning was
subsequently done after intervals of 10 minutes, 20 minutes, 40 minutes, and
60 minutes. The lowest degree of learning, Learning III, continued only
until the criterion of an average of 4.5 correct anticipations on two succes-
sive trials was reached, and relearning was conducted after the same
retention intervals as in Learning II.

Immediate relearning, as a control test, is provided for the two lower
degrees of learning in the complete learning records of the highest degree
of learning. For example, in meeting the highest criterion of learning, 12
correct anticipations on a single trial, the learner passes the lower criterion
of an average of 7 correct anticipations on two successive trials. The
memorization from this point on constitutes the immediate relearning for
the lower degree of learning.

The mnemonic material consisted of 36 nonsense-syllable lists constructed
according to a current elaboration of G. E. Müller's (33) rules.[1] Each list
had an average association value, based on Glaze's results (11), between
25.56 and 29.44 per cent. No single syllable with an association value
higher than 53.33 per cent was used.

[1] The nonsense-syllable lists used in the experiment and the rules by which they were
constructed may be found at the end of the article.

The subjects were fifteen Yale University students. They reported at the same hour at least five days each week and learned no more than one new list a day. Each subject, after six practice sessions, completed two cycles of the above fifteen retention conditions—a total of thirty-six experimental sessions.

A typewritten sheet of instructions,[2] closely resembling Ward's, was read by the subject on the first day and reread to the subject on the sixth practice session. He was then seated in front of the exposure apparatus, a modified
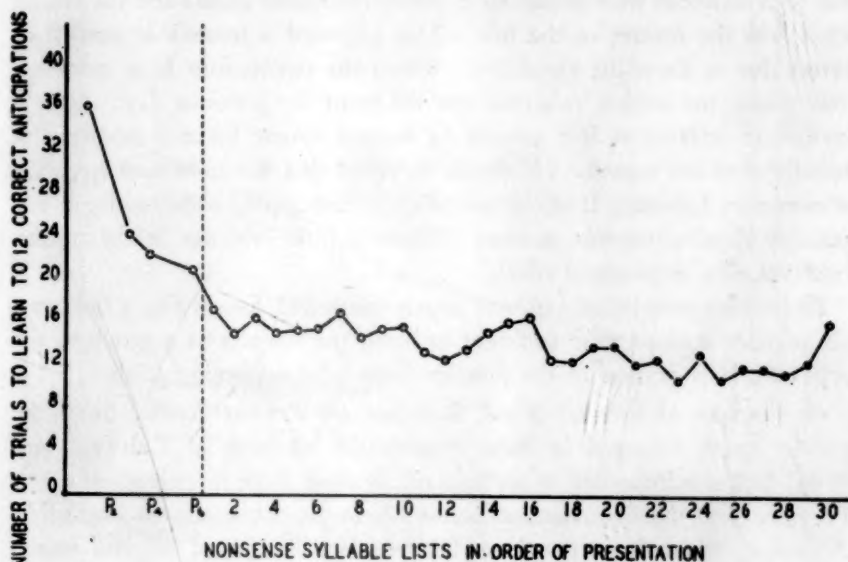
FIG. 1. PRACTICE CURVE FOR NUMBER OF LEARNING TRIALS DURING EXPERIMENT

The number of trials to learn to 12 correct anticipations is indicated for each nonsense-syllable list in the order of presentation. The vertical broken line marks the end of the practice and the beginning of the experimental sessions. Each point to the left of this line shows the mean trials for 15 subjects to learn the rote-series while the points to the right indicate the mean trials required by 7 subjects to learn the rote-series to the above criterion.

Chicago Memory drum. This drum, bearing the nonsense-syllable lists, made 30 intermittent movements per revolution with a 2-second interval between each movement. In this way a new syllable was shifted into the aperture every 2 seconds with 6 seconds elapsing between list presentations. The subject, after the first trial, anticipated by spelling out the nonsense-syllable, just before it appeared in the window. The subject continued anticipating the syllables until the criterion appropriate for that sitting had been reached.

[2] The directions for the subjects may be found in the Appendix.

In order to prevent rehearsal, Ward's method of having the subjects rest or read magazines in the retention interval was modified. The subjects read and ranked jokes at a table in the experimental room for 10 minutes after the learning session and 10 minutes before relearning. The 10- and 20-minute intervals were entirely taken up with this additional experimental task. After the retention interval the subjects relearned the series to the criterion of one errorless anticipation of the entire list.

The nonsense-syllable lists were learned in the same order by each subject, but the conditions were presented in counter-balanced orders and the second cycle was the reverse of the first. This provided a reasonable control of errors due to list-to-list variability. When the twenty-four hour retention was tested, the subject relearned the list from the previous day. After a 30-minute interval of free activity he learned a new list and relearned it usually after ten minutes. It should be noted that the 10-minute retention session after Learning II of the second cycle came, quite consistently, in this possibly disadvantageous position. There is little evidence in the results, however, of a detrimental effect.

Progressive practice effects were largely controlled, for, as Fig. 1 indicates, six practice sessions were sufficient to bring the subjects as a group to the relatively level portion of the practice curve [3] for relearning trials.

Comparison of Results: Ward, Luh and the Present Study. Since the present study followed in most respects the methods of Luh (23) and Ward (45) it is important to see how nearly these three investigations agree. Figure 2 gives the five retention points where direct comparison is possible. A close correspondence is evident between Ward's control test and immediate relearning in the present study; likewise, between Luh's 60-minute retention value and the hour retention of the present study. At the other retention intervals the results are not widely disparate, but the differences which do exist demand some comment.

At the 10- and 20-minute retention intervals the mean number of syllables retained is consistently higher in the present study than in Ward's and Luh's. Is it possible that less forgetting occurs during this occupation of rating jokes than during the casual reading and resting in Ward's experiment? Luh's results are based on 28 records for 8 subjects. Ward's findings are based on 24 records for 12 subjects. The results in the present study are based on 30 records for 15 subjects—in addition to the six practice sessions. It is very possible that the superior training of the subjects in the

[3] The data from which Figure 1 and the later figures are derived, are presented in detail in the appendix of the dissertation on file in the Yale University Library.

present study results in slightly superior levels of retention after short intervals of time.

At 24 hours Luh's subjects retained a slightly greater number of syllables than the subjects of the present experiment. It is probable that Luh's subjects were told, or inferred from the conditions of the experiment, that they would have to recall the syllables at a later date. In this study the 24-hour retention test was a surprise to the subjects. Geyer (10) found that any change in the expected time of recall had a deleterious effect on
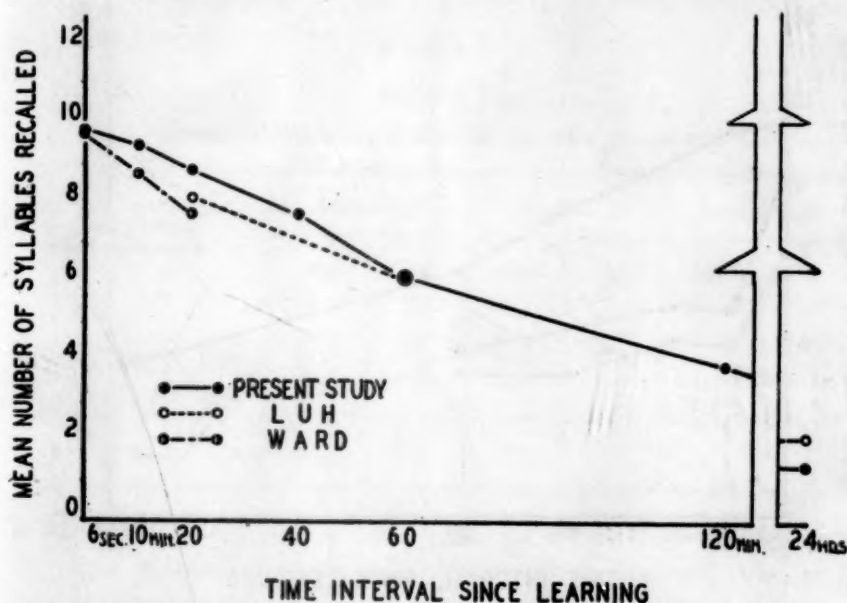
FIG. 2. MEAN RECALL SCORES COMPARED FOR THREE INVESTIGATIONS: WARD, LUH AND THE PRESENT STUDY

Mean recall scores, which are the mean number of syllables anticipated on the first relearning trial, are compared for three studies. Time is in minutes except for the 6-second interval and the 24-hour interval. The discontinuous abscissa indicates the unrecorded passage of 22 hours. Luh's results are based on 28 records for 8 subjects; Ward's are based on 24 records for 12 subjects; and the results of the present study are based on 30 records for 15 subjects. A record includes the learning and relearning of a single rote-series.

the amount recalled by the subjects. In accordance with these results it is to be expected that the 24-hour recall for the present study would be lower than Luh's. However, there is little reason to regard one set of results as more adequate than the others. The differences obtained must be attributed to the slight variations in the selection of the subjects or the methods employed.

A Comparison of the Various Measures of Retention. The comparisons with previous studies above have been based entirely on recall scores at the first relearning trial. There are four other common measures of retention, *i.e.,* number of relearning trials, total errors in relearning, savings scores, and second recall score. When the material has been learned to a fair degree of integration and forgetting has not progressed very far, there is close agreement between these measures.[4] When all the degrees of learning and all the retention intervals are considered, the number of relearning
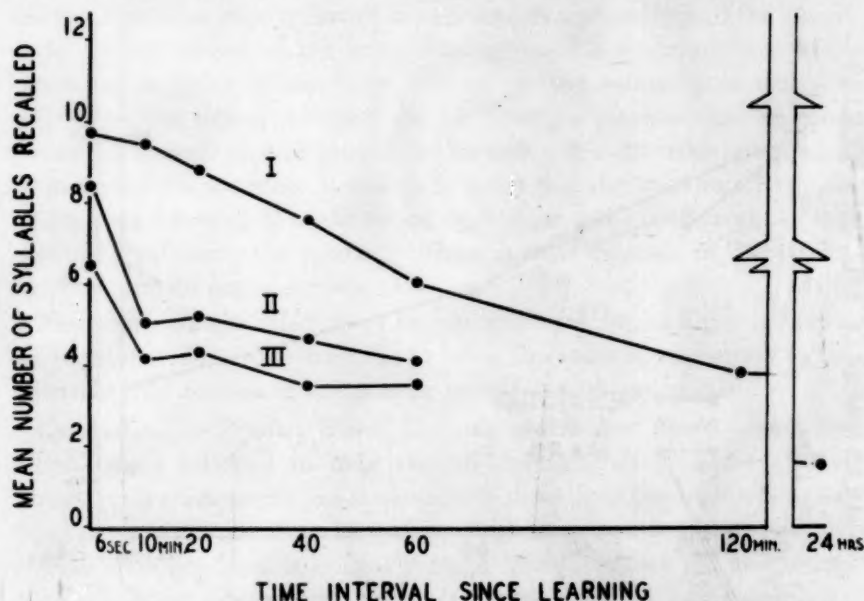
FIG. 3. RETENTION CURVES BASED ON RECALL SCORES FOLLOWING THREE DEGREES OF PARTIAL LEARNING

These retention curves following three degrees of partial learning are based on the mean number of syllables recalled on the first relearning trial. Curve I indicates retention after learning to 12 correct anticipations on a single trial. Curves II and III show retention after learning to averaged criteria, 7 correct anticipations and 4.5 anticipations respectively. Time is in minutes except for the 6-second and 24-hour intervals. Each point represents the mean of 30 records for 15 subjects.

trials and the errors in relearning are the most representative of the measures because they correlate to a high degree with all the retention measures. Recall I, which is the amount of the material which is immediately remembered, has significance in itself which more than compensates for its variability. Consequently, retention for partial learning will be presented

[4] The intercorrelations between all the measures of retention at each retention interval are presented in the appendix of the dissertation on file in the Yale University Library.

according to the three measures, relearning trials, errors in relearning and recall I.

Retention Following Three Degrees of Partial Learning. The progress of forgetting in terms of recall score after various intervals of time following three degrees of partial learning is shown in Figure 3 and Table I. As previously mentioned, curve I represents retention after the highest degree of learning, or 12 correct anticipations on a single trial. The next trial after the criterion was reached corresponds to the control trial of Ward's study.

TABLE I

RECALL I

MEAN NUMBER OF SYLLABLES ANTICIPATED ON FIRST RELEARNING TRIAL

TIME INTERVAL SINCE LEARNING	LEARNING I		LEARNING II		LEARNING III	
	M_N	σ_M	M_N	σ_M	M_N	σ_M
6"	9.80	0.38	8.39	0.16	6.45	0.27
10'	9.47	0.34	5.07	0.33	4.17	0.29
20'	8.90	0.33	5.20	0.43	4.23	0.27
40'	7.63	0.57	4.67	0.34	3.50	0.33
60'	6.07	0.49	4.10	0.37	3.53	0.37
120'	3.87	0.45				
24 Hours	1.40	0.34				

It is here designated as a retention point for the 6-second time interval. The large difference between the criterion and the observed value at 6 seconds is adequately explained as a function of criterial selection, Melton (30). In curve II the material was learned to a criterion of an average of 7 correct anticipations on two successive trials. The average number of anticipations on the last criterial trial was 7.57. The 6-second retention score for this curve was 8.39 syllables. In the case of the lowest degree of learning, *i.e.*, that based on an average criterion of 4.5 syllables anticipated on two successive trials, the mean number of syllables spelled on the last learning trial was 5.05. At the 6-second recall test (the next learning trial) the mean number of syllables recalled was 6.45. The relationship between the last relearning trial and the control test is, presumably, a function of the acceleration of the learning curve at the point where the learning is terminated.

In general these curves based on recall conform to the negatively accelerated forgetting curve of Ebbinghaus. In the two lower degrees of learning

the forgetting, for the most part, occurs within the first 10 minutes. The slight tendency for the retention curve to level off at the lowest degree of learning, may mean only that recall, as a retention measure, does not register adequately the slight differences in retention which still exist.

The retention curves for the three degrees of learning based on the number of trials in relearning appear in Fig. 4 with the data summarized in Table II. Several irregularities in these curves demand explanation. In curve I, retention following the highest degree of learning, the subjects relearned
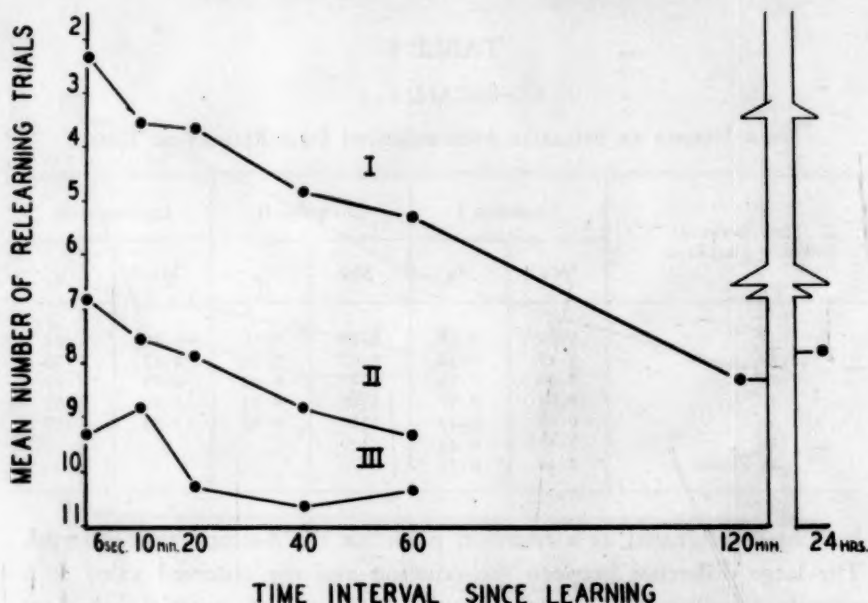
FIG. 4. RETENTION CURVES BASED ON RELEARNING TRIALS FOLLOWING THREE DEGREES OF PARTIAL LEARNING

These retention curves following three degrees of partial learning are based on the mean number of trials, including the criterion trial, required to relearn to 12 correct anticipations on a given trial. Curve I indicates retention after learning to 12 correct anticipations on a single trial. Curves II and III show retention after learning to averaged criteria, 7 correct anticipations and 4.5 correct anticipations respectively. Time is in minutes except for the 6-second and 24-hour intervals. Each point represents the mean of 30 records (relearning of 30 rote-series) for 15 subjects.

with fewer trials at the end of 24 hours than after 2 hours. This is probably due to diurnal variation. In keeping the beginning of the experimental sessions constant for all subjects the 2-hour retention was thrust somewhat later in the day. The subjects, no doubt, were more fatigued and took longer to relearn than in the case of the 24-hour retention. The first order reversals in the retention curves found by Radossawljewitch (35)

have been shown by Finkenbinder (9) to be the result of this same factor. Luh (23) prevented a first order reversal and secured fewer relearning trials at his 4-hour retention interval by shifting some of his experimental sessions to the morning. It was impossible to arrange morning sessions for the subjects in this study even if it had seemed desirable to do so.

The chief irregularity in these curves occurs at the 10-minute retention point for the lowest degree of learning. When the data for Cycle I and Cycle II are plotted separately this first order reversal occurs in both curves—

TABLE II

Mean Number of Relearning Trials

Time Interval Since Learning	Learning I		Learning II		Learning III	
	M_N	σ_M	M_N	σ_M	M_N	σ_M
6"	2.30	0.23	6.81	0.37	9.29	0.58
10'	3.57	0.29	7.57	0.40	8.83	0.57
20'	3.63	0.30	7.83	0.40	10.27	0.85
40'	4.83	0.34	8.83	0.81	10.63	0.59
60'	5.37	0.44	9.30	0.70	10.37	0.75
120'	7.80	0.55				
24 Hours	7.30	0.42				

an indication that it is probably not due solely to chance variation. It may be a remnant of the reminiscence effect which Ward obtained so clearly at the 2-minute retention interval, even though it appears only when relearning trials are considered. Can we infer that the lower the degree of learning the longer the reminiscence effect is likely to operate?

In general the retention curves based on relearning trials for Cycle I and Cycle II show only minor irregularities for the two higher degrees of learning. For the lowest degree of learning, on the other hand, Cycle II requires consistently fewer trials to relearn than Cycle I. It can be inferred from this that the additional practice before Cycle II affects this lower degree of learning more markedly than it affects the higher degrees of learning.

In Figure 5 the retention curves are based on the number of errors in relearning. The irregularities evident in the retention curve for the lowest degree of learning based on relearning trials, are somewhat less apparent when the curves are based on this more stable measure. The data for Figure 5 are summarized in Table III.

Variability in Retention Curves Following Low Degrees of Partial Learning. The excessive variability found by Ward (45) at his lowest degree of learning has already been mentioned. The averaged criterion of learning in the present study was used to overcome, if possible, some of the variable influences. The retention curves obtained in this manner are considerably less variable than Ward's (Figure 6). Since the lowest degree
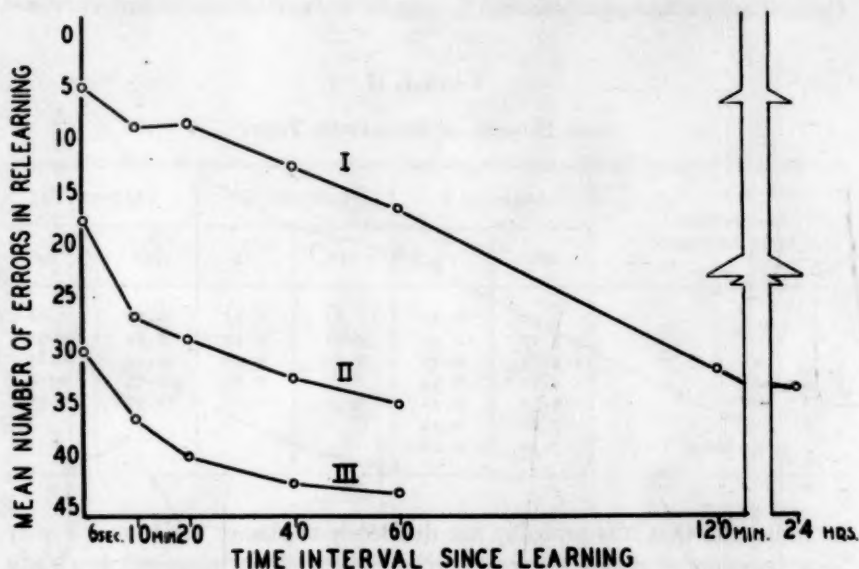
Fig. 5. RETENTION CURVES BASED ON ERRORS IN RELEARNING FOLLOWING THREE DEGREES OF PARTIAL LEARNING

These retention curves following three degrees of partial learning are based on the mean number of errors incurred in relearning to 12 correct anticipations on a given trial. Curve I indicates retention after learning to 12 correct anticipations on a single trial. Curves II and III show retention after learning to averaged criteria, 7 correct anticipations and 4.5 correct anticipations respectively. Time is in minutes except for the 6-second and 24-hour intervals. Each point represents the mean of 30 records for 15 subjects.

of learning studied in this experiment lies on the criterion continuum about half-way between Ward's two low degrees of learning, the greater stability observed in the present experiment may be due more to the higher degree of learning studied than to the method of criterial selection. In spite of minor irregularities this low degree of learning seems sufficiently consistent to serve as a basis for subsequent analysis of Jost's laws.

TABLE III

Mean Number of Errors in Relearning

Time Interval Since Learning	Learning I		Learning II		Learning III	
	M_N	σ_M	M_N	σ_M	M_N	σ_M
6″	4.27	0.73	16.71	1.66	29.71	2.51
10′	7.70	1.32	26.33	2.65	35.77	3.18
20′	7.60	0.77	27.63	2.17	39.00	4.06
40′	11.90	1.56	32.37	3.30	42.20	5.03
60′	16.07	1.75	34.60	3.09	42.53	3.76
120′	31.33	2.58				
24 Hours	33.00	2.27				
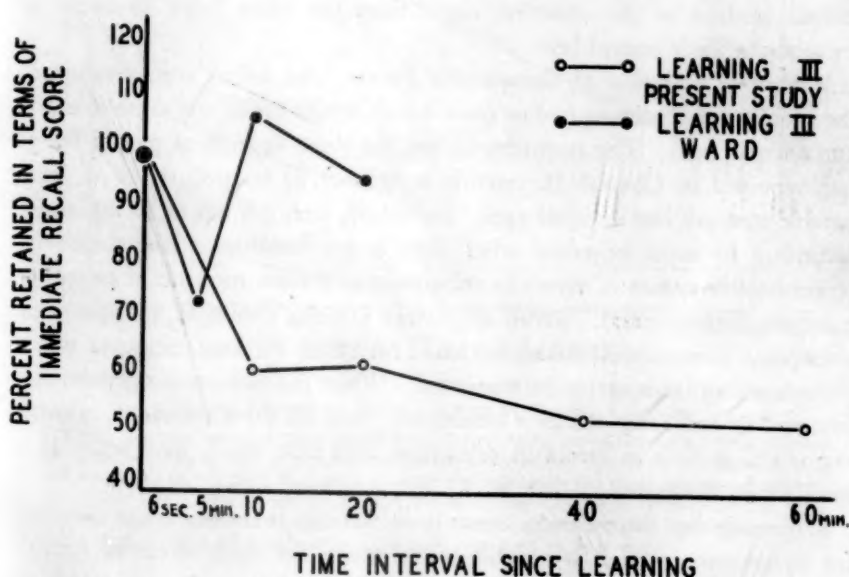
Fig. 6. Comparison of Variability in Recall Scores at the Lowest Degree of Learning for Ward's Experiment and the Present Study

Retention curves based on the per cent of the immediate recall score and presented for the lowest degree of learning in Ward's experiment and the present study. Ward's lowest degree of learning resulted from a single presentation of the material. In the present study an averaged criterion of 4.5 anticipations on 2 successive trials was used. Time is in minutes except for the 6-second interval. Each point on Ward's curve is the mean of 24 records on 12 subjects. Each point from the present study is the mean of 30 records on 15 subjects.

CHAPTER III

AN EVALUATION OF JOST'S LAWS

BEFORE more basic assumptions can be approached, there is need to clarify three aspects of Jost's laws at the relatively superficial level implied in their statement.[1] First, the effect of a single repetition on the younger and older habits must be demonstrated to test Jost's first law in its original form. Second, the superior value of the older over the younger habit during the entire course of relearning must be shown in order to confirm Jost's first law in the expanded form. Finally, the younger habit must be shown to fall off more rapidly in time, *i.e.*, to be situated at a steeper portion of the retention curve than the older habit in order to corroborate Jost's second law.

Method of Selection of Comparable Points. An initial consideration is the problem of obtaining two or more habits which are of the same strength but unequal ages. The retention curves, for three degrees of partial learning, reported in Chapter II, provide a number of learned series of comparable strength but unequal ages. Obviously, strength has to be measured according to some criterion other than a test measure. Elsewhere the representative nature of errors in relearning as a basic measure of retention has been demonstrated. Recall is another obvious choice as a measure of retention. Comparability may be based on either of these measures when the relearning trials are to be compared. When the difference between the first and second recall scores is considered, then, all three measures, relearning trials, as well as errors in relearning and first recall, may serve as a basis for equivalence.

Supposing that the measure, errors in relearning, is chosen as the criterion for equivalence, then it is possible to cut across the three retention curves, selecting the point on each where the number of errors in relearning is practically equivalent. Thus, these three points will have equal strength but will be of unequal age. The older habit in every case has been learned to a higher degree of original learning but has been forgotten, in the time interval since learning, to a degree comparable to the younger habit. Thus, in Figure 7, certain equivalent points on the three retention curves for errors in relearning are indicated.

[1] In this attempt Jost's terminology will be employed to a great extent.

The retention curve following the highest degree of original learning is designated Curve I and the curves after lower degrees of original learning are identified as II and III respectively. For further convenience in identification any single retention point will be symbolized by a Roman numeral to represent the curve and a figure subscript to represent the retention interval. Thus, I_{120} means the 120-minute or 2- hour retention point on the forgetting curve following the highest degree of learning. Similarly, II_{40} indicates the 40-minute retention point on curve II, and $III_{6''}$ means the
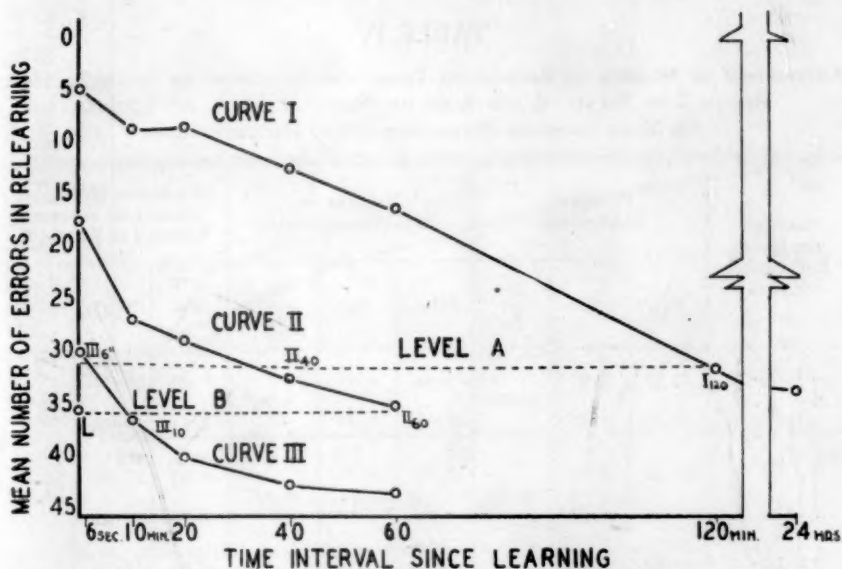
Fig. 7. Equivalent Points in Terms of Errors to Relearn: Indicated on Retention Curves Following Three Degrees of Partial Learning

Three comparable points are selected from the retention curves following three degrees of partial learning at each level indicated by the broken lines, A and B. At Level A, one point on each curve, $III_{6''}$, II_{40} and I_{120}, incur approximately the same number of relearning errors. At Level B, one point from Curve II, II_{60}, one point from Curve III, III_{10}, and the corresponding value from the course of learning are practically equivalent. The other characteristics of these curves have been presented in Figure 5.

6-second or immediate relearning point on the retention curve for the lowest degree of original learning. Furthermore, in Figure 7, the retention points, $III_{6''}$, II_{40} and I_{120} may be said to have approximately equal associative strength, according to the present criterion, for each incurs about the same number of errors in relearning. They are, however, of different ages for different intervals of time have elapsed since the point of original learning.

Before proceeding to use these three points to check Jost's laws, the essential equivalence between them must be demonstrated. In Table IV

the critical ratios of the differences between the mean number of relearning errors for the compared points are seen to vary from 0.30 to 0.79.

In the present study a quite arbitrary 0.90 has been used as the upper limit for critical ratios of equivalent points. Thus, in the case of even the most disparate of the compared younger and older habits there are only eighty-two chances in one hundred that a true difference exists. Accordingly, these points, compared in Table IV, may be considered roughly equivalent. A comparison of recall and relearning scores at these points

TABLE IV

COMPARISON OF NUMBER OF RELEARNING TRIALS AND INCREMENT IN SYLLABLES FROM RECALL I TO RECALL II FOR PAIRS OF POINTS AT LEVEL A[2] EQUATED FOR MEAN ERRORS IN RELEARNING BUT OF DIFFERENT AGES

YOUNGER AND OLDER EQUIVALENT POINTS	ERRORS IN RELEARNING			NUMBER OF RELEARNING TRIALS			INCREMENT IN NUMBER OF SYLLABLES FROM RECALL I TO RECALL II		
	M_N	σ_M	$\dfrac{D}{\sigma_D}$	M_N	σ_M	$\dfrac{D}{\sigma_D}$	M_N	σ_M	$\dfrac{D}{\sigma_D}$
Y III₆"	29.71	2.51	0.79	9.29	0.58	0.74*	0.63	0.12	3.09*
O II₄₀	32.37	3.30		8.83	0.81		1.53	0.24	
Y II₄₀	32.37	3.30	0.30	8.83	0.81	1.18*	1.53	0.24	2.60*
O I₁₂₀	31.33	2.58		7.80	0.55		2.60	0.45	
Y III₆"	29.71	2.51	0.45	9.29	0.58	1.86*	0.63	0.12	3.85*
O I₁₂₀	31.33	2.58		7.80	0.55		2.60	0.45	

* A confirmation of Jost's first law.
[2] Level A refers to the points identified as Level A on Figure 7. The data presented in Table IV will later be graphed as "Curve A". The source can readily be identified as three equivalent points at Level A on the retention curves based on errors in relearning.

provides a check of Jost's first law in both the original and the expanded form.

Check of Jost's First Law: Equivalence Based on Errors in Relearning. To confirm Jost's first law as he stated it, the older habit must profit more than the younger on a new repetition. A greater gain must be manifest between the first relearning trial and the second relearning trial in the case of the older habit than in the case of the younger. Jost's first law based on this increment for the three pairs of points analyzed in Table IV is plotted as Level A in Figure 8. The consistent rise of this curve supports

Jost's first law even more than do the critical ratios of the differences between the various pairs of points in Table IV. Additional confirmation of Jost's first law is seen in Level B of Figure 8. This curve is based on three more comparable points selected at Level B from the retention curves based on number of errors in relearning, Figure 7; namely, (1) the point in learning where an average of 35 relearning errors are made, (2) III_{10} and (3) II_{60}. The essential equivalence of these points, the mean differ-
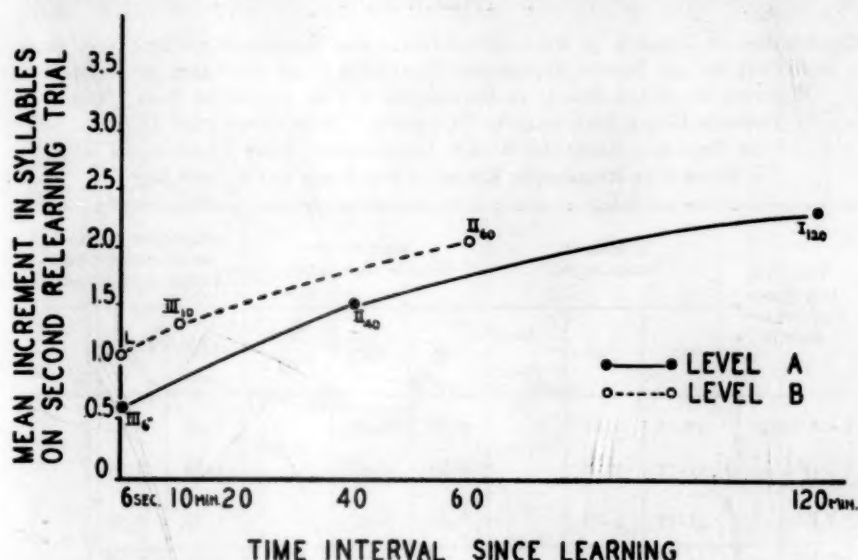
Fig. 8.   Curves Illustrating Jost's First Law: For the Comparable Points of
Levels A and B, Whose Equivalence Is Based on Mean
Number of Errors in Relearning

These curves show the amount of gain in number of syllables from the first relearning trial to the second for the comparable points of Levels A and B. The essential equivalence of the points for each level has been demonstrated on the retention curves based on errors in relearning following three degrees of partial learning. Time is in minutes except for the first retention interval, which represents the immediate relearning and conforms to the usual time spacing between trials in the course of learning. The points at the 6-second interval are based on 330 records for 15 subjects. The other points are the mean of 30 records for 15 subjects.

ences between Recall I and Recall II and the critical ratios involved are presented in Table V.

It is apparent that the critical ratios of the differences between Recall I and Recall II are not always significant. At least two factors are operative in determining the observed $\dfrac{D}{\sigma_D}$ values. There still exists a certain disparity in original equating. If the older habit retains a slight advantage over the younger, then, on the related test-values in relearning and recall, a similar

advantage might be expected. This slight superiority would tend to exaggerate the $\dfrac{D}{\sigma_D}$ value confirming Jost's law. If, on the other hand, the younger habit had the original advantage, the resultant critical ratio, indicating the reliability of a Jost law confirmation, might be appreciably lowered. When the distorting effect of disparity in original equating is

TABLE V

COMPARISON OF NUMBER OF RELEARNING TRIALS AND INCREMENT IN SYLLABLES FROM
THE FIRST TO THE SECOND RELEARNING TRIALS FOR PAIRS OF POINTS AT LEVEL B
EQUATED FOR MEAN ERRORS IN RELEARNING BUT OF DIFFERENT AGES. THE
YOUNGER HABIT, IDENTIFIED AS "LEARNING", REPRESENTS THAT DEGREE
OF ORIGINAL LEARNING WHICH CORRESPONDS MOST CLOSELY IN
NUMBER OF RELEARNING ERRORS TO THE SCORE AT III_{10} AND II_{60}

YOUNGER AND OLDER EQUIVALENT POINTS	ERRORS IN RELEARNING			NUMBER OF RELEARNING TRIALS			INCREMENT IN NUMBER OF SYLLABLES FROM RECALL I TO RECALL II		
	M_N	σ_M	$\dfrac{D}{\sigma_D}$	M_N	σ_M	$\dfrac{D}{\sigma_D}$	M_N	σ_M	$\dfrac{D}{\sigma_D}$
Learning	35.05	0.21	0.22	9.52	0.20	1.31*	1.09	0.14	0.66*
O III_{10}	35.77	3.18		8.83	0.57		1.33	0.35	
Y III_{10}	35.77	3.18	0.30	8.83	0.57	0.53†	1.33	0.35	2.02*
O II_{60}	34.60	3.09		9.30	0.70		2.10	0.17	
Learning	35.05	0.21	0.14	9.52	0.20	0.34*	1.09	0.14	4.37*
O II_{60}	34.60	3.09		9.30	0.70		2.10	0.17	

* Confirmation of Jost's first law.
† Contradiction of Jost's first law expanded.

disregarded, there still remains the factor of qualitative dissimilarity of the two habits compared. There are actually two variables operative, time since original learning and degree of original learning. Since these vary concomitantly in the present study, they can temporarily be regarded as age differences. There is an indication that the greater the age differences between the compared habits the larger the critical ratio of the increment on Recall II.

In spite of the low $\dfrac{D}{\sigma_D}$ values for some of the comparisons, when the equivalence of the learned series is based on errors in relearning, Jost's first

law is consistently confirmed. In every case the "older habit has more value on a new repetition".

Check of Jost's First Law: Equivalence Based on Recall I. In a similar manner, comparable points may be selected from the retention curves based on Recall I. Broken lines cutting the retention curves in Figure 9 indicate the three levels at which at least three comparable points are available. They are variously identified as Level C, D, and E. At Level E, the three
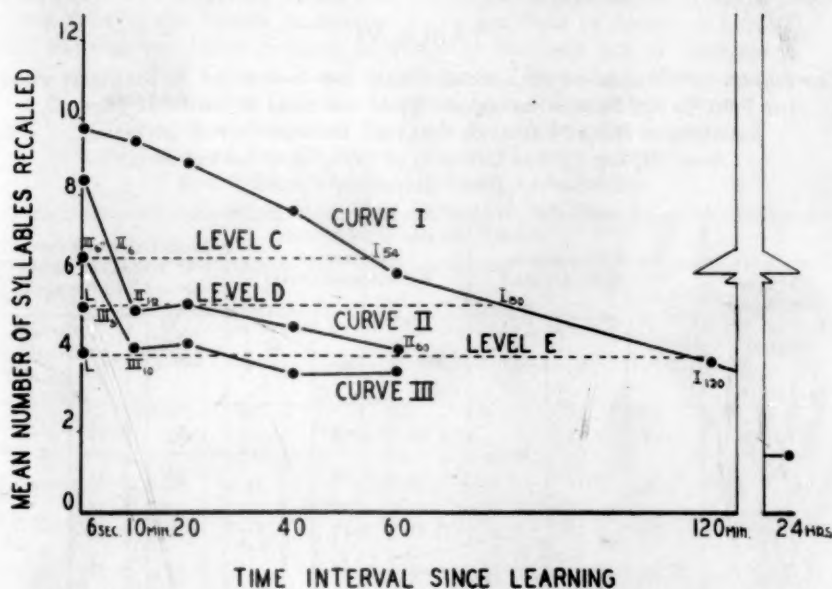
FIG. 9. EQUIVALENT POINTS IN TERMS OF RECALL INDICATED ON RETENTION CURVES FOLLOWING THREE DEGREES OF PARTIAL LEARNING

Comparable points are selected from the retention curves based on recall scores following three degrees of partial learning at three levels indicated by the broken lines, C, D and E. At Level C one point is selected from each curve: $III_6{}^u$ is an observed point from the course of learning; II_6 is an interpolated point three-fifths of the distance from $II_6{}^u$ to II_{10}; I_{54} is an interpolated point two-thirds of the distance from the observed points I_{40} and I_{60}. At Level D a point is selected from each curve with a fourth point available at the corresponding value in learning: III_6 is an interpolated point for which the values at $III_6{}^u$ and III_{10} are averaged; II_{10} is selected from Curve II; I_{90} is an interpolated point one-third of the distance between I_{60} and I_{120}, and these values are weighted appropriately in deriving I_{90}. At Level E three observed points are chosen; III_{10}, II_{60} and I_{120}, along with a fourth point from the corresponding stage in the course of learning. The characteristics of these curves have been previously presented in Figure 3.

retention points, I_{120}, II_{60}, and III_{10}, are available in addition to a fourth point from the original learning. At the higher levels on the retention curves it is occasionally necessary to use interpolated retention points inter-

mediate between the observed retention intervals on any given curve.[3] In most cases the mean of the adjacent retention values is employed for later comparisons. The extent of equivalence of the points within these levels when paired for comparison, the difference in each case between Recall I and II, and the respective critical ratios are summarized in Tables VI, VII and VIII.

In all but one case, *i.e.,* the first comparison of Table VII, the older habit shows more value on *a* new repetition. Considerable doubt may be cast on

TABLE VI

COMPARISON OF NUMBER OF RELEARNING TRIALS AND INCREMENT IN SYLLABLES FROM THE FIRST TO THE SECOND RELEARNING TRIAL FOR PAIRS OF POINTS AT LEVEL C, EQUATED FOR MEAN NUMBER OF SYLLABLES RECALLED BUT OF DIFFERENT AGES. II_6 AND I_{54} ARE OBTAINED BY WEIGHTING APPROPRIATELY THE ADJACENT RETENTION VALUES

YOUNGER AND OLDER EQUIVALENT POINTS	MEAN NUMBER OF SYLLABLES RECALL I			NUMBER OF RELEARNING TRIALS			INCREMENT IN NUMBER OF SYLLABLES FROM RECALL I TO RECALL II		
	Mn	σ_M	$\frac{D}{\sigma_D}$	Mn	σ_M	$\frac{D}{\sigma_D}$	Mn	σ_M	$\frac{D}{\sigma_D}$
Y III_6	6.45	0.27	0.13	9.29	0.58	4.21*	0.63	0.12	2.60*
O II_6	6.39	0.28		7.27	0.25		1.30	0.21	
Y II_6	6.39	0.28	0.31	7.27	0.25	5.83*	1.30	0.21	2.40*
O I_{54}	6.59	0.44		5.19	0.35		2.17	0.36	
Y III_6	6.45	0.27	0.24	9.29	0.58	6.03*	0.63	0.12	4.75*
O I_{54}	6.59	0.44		5.19	0.35		2.17	0.36	

* A confirmation of Jost's first law.

the validity of this contradiction. The observed difference favoring the younger habit instead of the older one is slight. Likewise, it can be questioned whether increment values based on III_5, an interpolated point between immediate relearning and relearning after ten minutes, is altogether trustworthy. This contradiction has so little significance compared with the many instances of confirmation that Jost's first law may again be considered demonstrated.

[3] This procedure would be orthodox enough if the curve were known to be linear. When the curve is not linear the values can still be interpolated, but it is difficult to calculate accurately the appropriate time interval for the derived retention value. This is particularly true when the reminiscence effect is known to complicate the curve; *e.g.,* for derived II_6 in Level C.

In addition to showing that the older habit has more value on a new repetition it now appears that the older the habit the greater the increment on a new repetition. In Figure 10 this relationship, especially Jost's law in graphic form, is presented for the three series of comparable points identified in Figure 9 as Series C, D and E. Although not entirely

TABLE VII

Comparison of Number of Relearning Trials and Increment in Syllables from the First to the Second Relearning Trials for Pairs of Points at Level D, Equated for Mean Number of Syllables Recalled but of Different Ages. The Younger Habit, Identified as "Learning", Represents the Degree of Original Learning which Corresponds Most Closely in Number of Syllables Recalled to the Scores at the Compared Points. Points III_5 and I_{80} Represent Interpolated Values Obtained by Averaging or Weighting Approximately the Adjacent Observed Values

Younger and Older Equivalent Points	Mean Number of Syllables Recall I			Number of Relearning Trials			Increment in Number of Syllables from Recall I to Recall II		
	Mn	σ_M	$\dfrac{D}{\sigma_D}$	Mn	σ_M	$\dfrac{D}{\sigma_D}$	Mn	σ_M	$\dfrac{D}{\sigma_D}$
Learning	5.25	0.11		10.35	0.54		1.04	0.16	
O III_5	5.32	0.19	0.27	9.06	0.53	4.59*	0.99	0.22	0.15†
Y III_5	5.32	0.19		9.06	0.53		0.99	0.22	
O II_{10}	5.07	0.33	0.71	7.57	0.40	2.32*	1.80	0.36	1.89*
Y II_{10}	5.07	0.33		7.57	0.40		1.80	0.36	
O I_{80}	4.97	0.42	0.24	5.17	0.23	5.97*	2.54	0.35	1.84*
Y III_5	5.32	0.19		9.06	0.53		0.99	0.22	
O I_{80}	4.97	0.42	0.70	5.17	0.23	6.43*	2.54	0.35	3.66*
Learning	5.25	0.11		10.35	0.54		1.04	0.16	
O II_{10}	5.07	0.33	0.50	7.57	0.40	4.45*	1.80	0.36	1.88*
Learning	5.25	0.11		10.35	0.54		1.04	0.16	
O I_{80}	4.97	0.42	0.66	5.17	0.23	9.45*	2.54	0.35	4.45*

* Confirmation of Jost's first law
† Contradiction of Jost's first law.

coinciding, there is a close correspondence between these curves; a remarkable agreement, considering that the curves are based on equivalent points at quite different levels of retention. The essential similarity may be attributed to the stabilizing influence of equating mean number of syllables recalled on the first relearning trial. The increment on the second relearning trial, then, is directly comparable for the younger and older habits; hence, the relatively regular functions in Figure 10. The essential loga-

TABLE VIII

COMPARISON OF NUMBER OF RELEARNING TRIALS AND INCREMENT IN SYLLABLES FROM THE FIRST TO THE SECOND RELEARNING TRIAL FOR PAIRS OF POINTS AT LEVEL E, EQUATED FOR MEAN NUMBER OF SYLLABLES RECALLED BUT OF DIFFERENT AGES. THE YOUNGER HABIT, IDENTIFIED AS "LEARNING", REPRESENTS THE DEGREE OF ORIGINAL LEARNING WHICH CORRESPONDS MOST CLOSELY IN NUMBER OF SYLLABLES RECALLED TO THE SCORES AT THE COMPARED POINTS

YOUNGER AND OLDER EQUIVALENT POINTS	MEAN NUMBER OF SYLLABLES RECALL I			NUMBER OF RELEARNING TRIALS			INCREMENT IN NUMBER OF SYLLABLES FROM RECALL I TO RECALL II		
	M_N	σ_M	$\dfrac{D}{\sigma_D}$	M_N	σ_M	$\dfrac{D}{\sigma_D}$	M_N	$\sigma_{\bar{M}}$	$\dfrac{D}{\sigma_D}$
Learning	4.27	0.45	0.21	10.92	0.62	3.91*	0.79	0.11	1.41*
O III₁₀	4.17	0.29		8.83	0.57		1.33	0.35	
Y III₁₀	4.17	0.29	0.18	8.83	0.57	0.53†	1.33	0.35	1.96*
O II₆₀	4.10	0.37		9.30	0.70		2.10	0.17	
Y II₆₀	4.10	0.37	0.38	9.30	0.70	1.57*	2.10	0.17	0.99*
O I₁₂₀	3.87	0.45		7.80	0.55		2.60	0.45	
Y III₁₀	4.17	0.29	0.59	8.83	0.57	2.56*	1.33	0.35	2.19*
O I₁₂₀	3.87	0.45		7.80	0.55		2.60	0.45	
Learning	4.27	0.45	0.29	10.92	0.62	1.90*	0.79	0.11	7.75*
O II₆₀	4.10	0.37		9.30	0.70		2.10	0.17	
Learning	4.27	0.45	0.60	10.92	0.62	3.82*	0.79	0.11	4.06*
O I₁₂₀	3.87	0.45		7.80	0.55		2.60	0.45	

* Confirmation of Jost's first law.
† Contradiction of Jost's first law expanded.

rithmic form of the curves was revealed by plotting the antilogs of the various points. It was evident that a straight line was the best fit. A composite curve of the observed values would have the general form:

$$y = K \log t + c$$

where y is the increment on a new repetition, t is the time since learning and K and c are constants.

A Check of Jost's First Law: Equivalence Based on Number of Relearning Trials. Such regular functions demonstrating Jost's first law do not
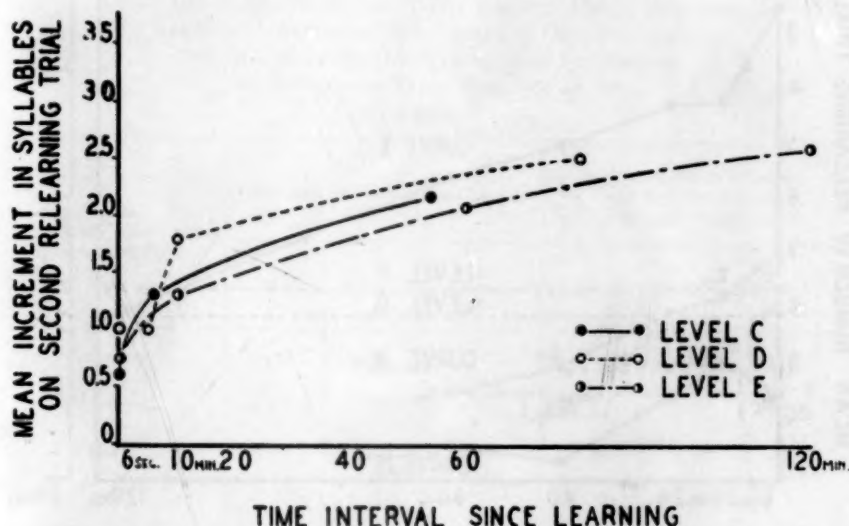
FIG. 10.   CURVES ILLUSTRATING JOST'S FIRST LAW FOR THE COMPARABLE POINTS OF LEVELS C, D AND E, WHOSE EQUIVALENCE IS BASED ON MEAN NUMBER OF SYLLABLES RECALLED

These curves show the amount of gain in number of syllables from the first relearning trial to the second for the comparable points of Levels C, D and E. The essential equivalence of the points for each level has been demonstrated on the retention curves based on syllables recalled at various intervals after three degrees of partial learning. Time is in minutes except for the first retention interval, which represents the immediate relearning and conforms to the usual time spacing between trials in the course of learning. The points at the 6-second interval are based on 330 records for 15 subjects. The other points are the mean of 30 records for 15 subjects.

occur when the equivalence of the comparable points is based on errors in relearning. The several available series for comparison are identified in Figure 11 as F, G, H and I. Since the comparable points are based on relearning trials, only the increment following the first relearning trial

can be meaningfully compared.[4] These data are summarized in Tables IX, X, XI and XII.

The progressive increase in the value of a new repetition as age increases, when equivalence is based on trials to relearn, is presented graphically in Figure 12. There is a certain correspondence between Series F, G and I but function H seems to be a different sort of curve, practically a straight line. There is no very obvious reason why Curves H and I should be dissimilar. Both curves include points in learning and points from the
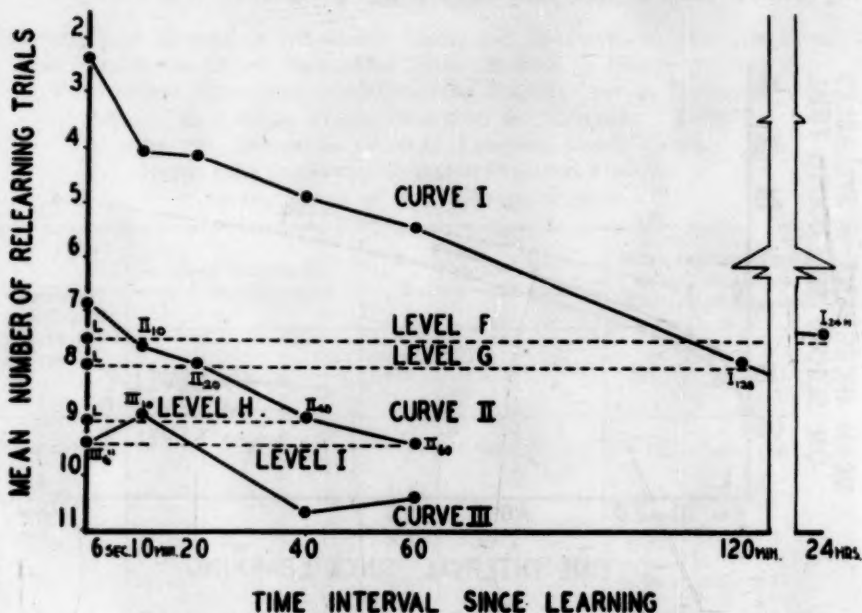
FIG. 11. EQUIVALENT POINTS IN TERMS OF RELEARNING TRIALS INDICATED ON RETENTION CURVES FOLLOWING THREE DEGREES OF PARTIAL LEARNING

Comparable points are selected from the retention curves based on relearning trials following three degrees of partial learning at four levels indicated by the broken lines, F, G, H and I. At Level F two observed points, II_{10} and I_{34II} are selected along with one point from the corresponding stage in learning. At Level G the observed points I_{120}, II_{20} and a point in learning compose the series. At Level H, two observed points, II_{10} and III_{10} are added to the corresponding value in the learning. At Level I two points are selected from Curve III, III_{15} and III_{60}, the corresponding point in learning, along with II_{60}. III_{15} is an interpolated point, obtained by averaging the adjacent observed points. The characteristics of these curves have been presented previously in Figure 4.

[4] If the older habit profits more from the first relearning trial, as has just been shown, and the trials to relearn are equated, Recall I for the older habit must be appreciably lower at the beginning of relearning than for the younger. This means that more errors are made on the first relearning trial by the older than by the younger. It is not surprising that in some cases the older shows more total errors at the end of the relearning. However, under these conditions it is not reasonable to conclude that when the older incurred more errors in relearning, then Jost's first law is contradicted.

retention curves following the low degrees of learning. The greatest difference between them occurs at the immediate relearning point, where the values were determined by different methods. Learning was stopped for $III_{6''}$ when an average of 4.5 syllables were recalled on two successive trials. There is a factor of criterial selection (30) and the two trials beyond this criterion probably exhibit somewhat reduced values. On the other hand

TABLE IX

Comparison of Increment in Syllables from the First to the Second Relearning Trials for Pairs of Points at Level F, Equated for Mean Relearning Trials but of Different Ages. The Younger Habit, Identified as "Learning", Represents the Degree of Original Learning which Corresponds Most Closely to the Number of Relearning Trials Required at the Comparable Points

Younger and Older Equivalent Points	Number of Relearning Trials			Increment in Number of Syllables from Recall I to Recall II		
	M_N	σ_M	$\dfrac{D}{\sigma_D}$	M_N	σ_M	$\dfrac{D}{\sigma_D}$
Learning	7.50	0.00		0.59	0.04	
O II$_{19}$	7.57	0.40	0.17	1.80	0.36	3.61*
Y II$_{19}$	7.57	0.40		1.80	0.36	
O I$_{34''}$	7.30	0.42	0.40	3.20	0.32	2.98*
Learning	7.50	0.00		0.59	0.04	
O I$_{34''}$	7.30	0.42	0.47	3.20	0.32	8.45*

* Confirmation of Jost's first law.

the immediate relearning values for Level H were obtained by simply counting back 9 trials from the end of learning and recording the Recall I and Recall II scores noted after that point in memorization. The element of high criterial selection was absent. The resulting increment after one relearning trial was sufficiently higher to change the entire appearance of the curve for Jost's first law at this level.

Irrespective of the forms of the curves in Figure 12, the older habit is invariably seen to have greater value on a new repetition. There is a tendency again for more disparity in the ages of the comparable points to produce more reliable differences after a single relearning trial.

Jost's first law, as he stated it, has been amply confirmed in the foregoing presentation. Whether equivalence for the habits is based on errors, recall, or relearning trials, the older habit shows a greater increment in syllables recalled after a single relearning trial. The single exception, when III_5 and the corresponding point in learning are compared, has been shown to be quite unreliable. In addition to these demonstrations, Jost's first

TABLE X

COMPARISON OF INCREMENT IN SYLLABLES FROM THE FIRST TO THE SECOND RELEARNING
TRIALS FOR PAIRS OF POINTS AT LEVEL G, EQUATED FOR MEAN RELEARNING
TRIALS BUT OF DIFFERENT AGES. THE YOUNGER HABIT, IDENTIFIED AS
"LEARNING", REPRESENTS THE DEGREE OF ORIGINAL LEARNING
WHICH CORRESPONDS MOST CLOSELY TO THE NUMBER
OF RELEARNING TRIALS REQUIRED AT THE
COMPARABLE POINTS

YOUNGER AND OLDER EQUIVALENT POINTS	NUMBER OF RELEARNING TRIALS			INCREMENT IN NUMBER OF SYLLABLES FROM RECALL I TO RECALL II		
	M_N	σ_M	$\dfrac{D}{\sigma_D}$	M_N	σ_M	$\dfrac{D}{\sigma_D}$
Learning	8.00	0.00	0.42	0.49	0.15	1.45*
O II₂₀	7.83	0.40		1.27	0.46	
Y II₂₀	7.83	0.40	0.05	1.27	0.46	1.75*
O I₁₂₀	7.80	0.55		2.60	0.45	
Learning	8.00	0.00	0.36	0.49	0.15	4.42*
O I₁₂₀	7.80	0.55		2.60	0.45	

* Confirmation of Jost's first law.

law has been plotted graphically for the comparable points at the various levels. When the associations are equated for number of syllables recalled on the first relearning trial, the composite curve of increment on another repetition appears to be a logarithmic function. When the associations are equated for errors in relearning or trials to relearn, certain modifications in the form of the curves may occur, but, in general, they confirm the logarithmic trend.

Check of Jost's First Law Expanded: Equivalence Based on Errors in Relearning. As previously noted, Jost's first law has customarily been expanded to mean that the older habit requires fewer relearning trials than

the younger. That this expansion is partially justified can be seen by further examination of Tables IV and V. At the two levels A and B, the equivalent series of associations have been equated for errors in relearning. It can be seen that in every pair of points at Level A the older requires fewer relearning trials in accordance with the customary expansion of the law. These results appear in Figure 13 as the curve for Level A. However, a first

TABLE XI

Comparison of Increment in Syllables from the First to the Second Relearning Trials for Pairs of Points at Level H, Equated for Mean Relearning Trials but of Different Ages. The Younger Habit, Identified as "Learning", Represents the Degree of Original Learning which Corresponds Most Closely to the Number of Relearning Trials Required at the Comparable Points

Younger and Older Equivalent Points	Number of Relearning Trials			Increment in Number of Syllables from Recall I to Recall II		
	M_N	σ_M	$\dfrac{D}{\sigma_D}$	M_N	σ_M	$\dfrac{D}{\sigma_D}$
Learning	9.00	0.00	0.30	1.03	0.13	0.83*
O III$_{10}$	8.83	0.57		1.33	0.35	
Y III$_{10}$	8.83	0.57	0.00	1.33	0.35	0.42*
O II$_{40}$	8.83	0.81		1.53	0.24	
Learning	9.00	0.00	0.21	1.03	0.13	1.66*
O II$_{40}$	8.83	0.81		1.53	0.24	

* Confirmation of Jost's first law.

order reversal occurs in the curve for Level B, showing that in at least one comparison, the expanded form of Jost's first law is not confirmed. Reference to Table V reveals that the critical ratio of this difference is relatively low, only 0.53, but little may be inferred from this since the reliability of the differences between any of the pairs of points in Series A or B is low. More equivalent points must be compared before any conclusion can be drawn.

Check of Jost's First Law Expanded: Equivalence Based on Recall I. Three more series of comparable points, which are available when the equivalence is based on Recall I, have already been presented in Tables VI,

VII and VIII. In all but one instance the expanded form of Jost's First Law is justified. In Figure 14 the data are presented in graphic form. The curves for Levels C and D show a consistent decrease in the required number of relearning trials for the older habits. The curve for Level E, however, shows a first order reversal which seems to be produced by the same determination, II_{60}, which seemed out of line in the curve for Level I

TABLE XII

COMPARISON OF INCREMENT IN SYLLABLES FROM THE FIRST TO THE SECOND RELEARNING
TRIALS FOR PAIRS OF POINTS AT LEVEL I, EQUATED FOR MEAN RELEARNING
TRIALS BUT OF DIFFERENT AGES. THE YOUNGER HABIT, IDENTIFIED AS
"LEARNING", REPRESENTS THE DEGREE OF ORIGINAL LEARNING
WHICH CORRESPONDS MOST CLOSELY TO THE NUMBER
OF RELEARNING TRIALS REQUIRED AT THE
COMPARABLE POINTS

YOUNGER AND OLDER EQUIVALENT POINTS	NUMBER OF RELEARNING TRIALS			INCREMENT IN NUMBER OF SYLLABLES FROM RECALL I TO RECALL II		
	M_N	σ_M	$\dfrac{D}{\sigma_D}$	M_N	σ_M	$\dfrac{D}{\sigma_D}$
Y III_{8}	9.29	0.58	0.87	0.63	0.12	3.18*
O III_{15}	9.06	0.53		0.99	0.02	
Y III_{15}	9.06	0.53	0.29	0.99	0.02	6.85*
O II_{60}	9.30	0.70		2.10	0.17	
Y III_{8}	9.29	0.58	0.01	0.63	0.12	8.65*
O II_{60}	9.30	0.70		2.10	0.17	

* Confirmation of Jost's first law.

in the preceding Figure 12. Since the other points of the series do not coincide in the two figures, this duplication seems permissible. However, to consider the reversal in each curve, which may be due to chance variability at a single point in retention, as independent contradictions of Jost's law, is hardly warranted. Were it not for the single point at II_{60}, the associations at Level E would show close correspondence to Curves C and D of Figure 14. These three functions are derived from a series of points at different levels of retention value. The amount of retention, of course, determines the relative position of these curves, *i.e.*, whether a larger or smaller number of relearning trials is required.

It is apparent, from Tables VI, VII and VIII, that when the comparable points are selected with relatively high retention values, as in the curves for Levels C and D, the advantage of the older over the younger in relearning is generally reliable; $\dfrac{D}{\sigma_D}$ values range from 2.24 to 9.45. When the learning and retention value is low the $\dfrac{D}{\sigma_D}$ values range from 1.57 to 3.82 and the differences show, in one case, a reversal in which the younger

TIME INTERVAL SINCE LEARNING

Fig. 12.   Curves Illustrating Jost's First Law for the Comparable Points of
Levels F, G, H and I, Whose Equivalence Is Based on
Mean Number of Relearning Trials

These curves show the amount of gain in number of correct anticipations from the first relearning trial to the second for the comparable points of Levels F, G, H, and I. The essential equivalence of the points for each level has been demonstrated on the retention curves based on number of relearning trials at various intervals after three degrees of partial learning. Time is in minutes except for the first retention interval, which represents the immediate relearning and conforms to the usual time spacing between trials in the course of learning. The points at the 6-second interval are based on 330 records for 15 subjects. The other points are the means of 30 records for the 15 subjects.

associations are relearned with fewer trials. In summary, this means that as the amount of necessary relearning increases, the advantage of the older habit over the younger decreases. These results do not, however, indicate any necessary limits to Jost's first law expanded. In nineteen of the twenty paired comparisons the expanded form of Jost's first law is justified. When the data are plotted, showing the decrease in required relearning trials as age increases for the series of associations equated on initial recall,

fairly regular functions result. It appears likely that these curves belong to a single family with one or more variable parameters which assume different values for the different retention levels examined.

Check of Jost's Second Law. Jost states in his second law that "given two associations of the same strength but different ages the older falls off less rapidly in a given length of time" (20, *p. 472*). Of all the comparable
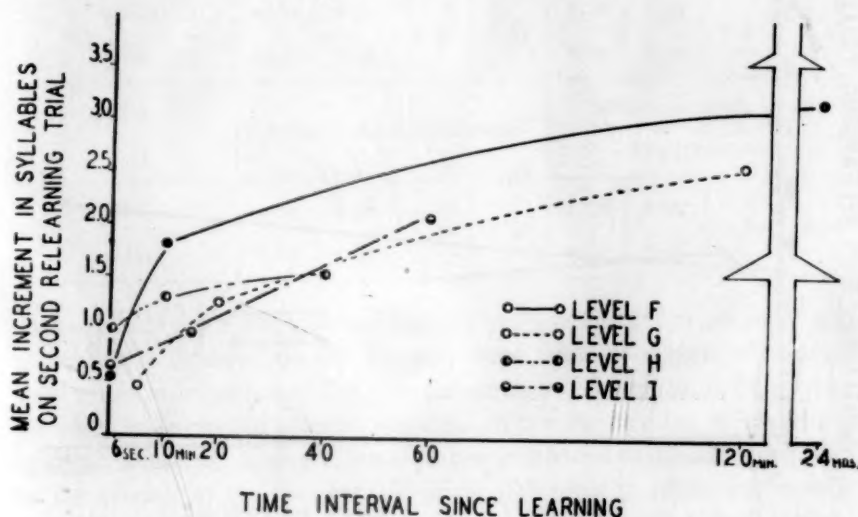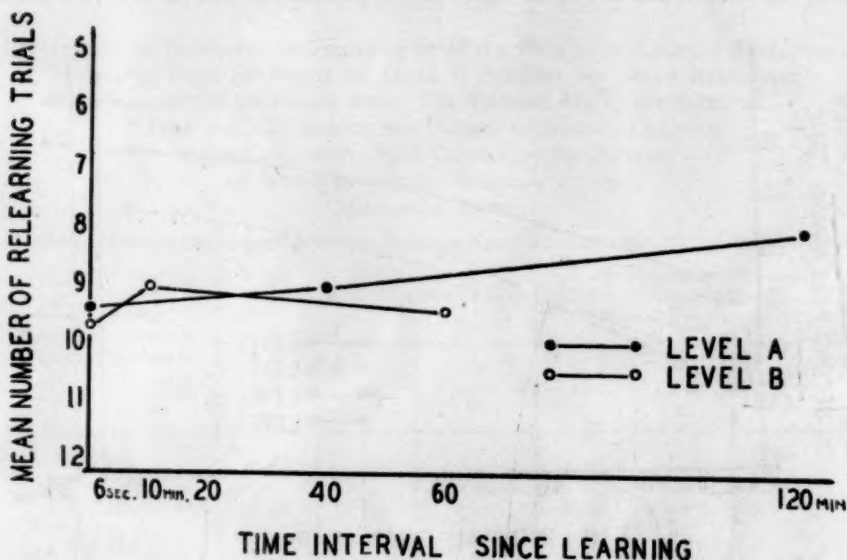

FIG. 13. CURVES ILLUSTRATING JOST'S FIRST LAW EXPANDED: FOR COMPARABLE POINTS OF LEVELS A AND B, WHOSE EQUIVALENCE IS BASED ON MEAN NUMBER OF ERRORS IN RELEARNING

These curves show the number of relearning trials required at the comparable points of Levels A and B to relearn to 12 correct anticipations on a single trial. The essential equivalence of the points at each level has been demonstrated on the retention curves based on mean errors in relearning after three degrees of partial learning. Time is in minutes except for the first retention interval, which represents the immediate relearning and conforms to the usual time spacing between trials in the course of learning. The points at the 6-second interval are based on 210 records for 15 subjects. The other points are the mean of 30 records for 15 subjects.

points provided by these retention curves following three degrees of partial learning only one pair provides a specific test of Jost's second law. The two points $III_{6''}$ and II_{40} in Figure 7 are each followed by observed retention points after an interval of 20 minutes. In order to confirm Jost's second law there must be a greater drop in the retention curve in 20 minutes

following the younger, $III_{6''}$, than following the older, II_{40}. A comparison of these two learned series after 20 minutes follows:

YOUNGER AND OLDER EQUIVALENT POINTS	MEAN ERRORS IN RELEARNING				MEAN ADDITIONAL ERRORS IN RELEARNING AFTER TWENTY MINUTES			
	M_N	σ_M	D	$\dfrac{D}{\sigma_D}$	M_N	σ_M	D	$\dfrac{D}{\sigma_D}$
Y $III_{6''}$	29.71	2.51	2.55	0.61	9.28	3.39	7.19	1.39
O II_{40}	32.37	3.30			2.09	3.92		
	MEAN TRIALS IN RELEARNING				MEAN ADDITIONAL TRIALS TO RELEARN AFTER TWENTY MINUTES			
Y $III_{6''}$	9.29	0.58	0.46	0.46	1.38	0.72	0.85	0.71
O II_{40}	8.83	0.81			0.53	0.96		

In accordance with Jost's second law the younger has fallen off more and consequently requires, on the average, more trials to relearn and incurs more errors in relearning. The younger acquires definitely more errors than the older in relearning after 20 minutes. When the number of relearning trials are compared, however, less than one more trial to relearn is required on the average by the younger. That the difference in relearning trials is so small and the reliability so low is not surprising for such a short interval of time as 20 minutes.

This second law assumes regular negatively-accelerated retention curves for all degrees of learning. When such curves are obtained, any cross-curve comparison for equivalent points must cut the curve for the younger habit at a steeper portion of the curve than in the case of the older habit. In general, the retention curves in the present study are negatively accelerated and, by inspection, Jost's second law appears to be confirmed at most of the available pairs of equivalent points. Whenever, though, a reliable first order inversion occurs in the retention curve, a true limit to Jost's second law may be demonstrated. In no case are the first order inversions observed in these data reliable enough to constitute a demonstrable limit to the second law. In Figure 11 there is a definite rise at the 10-minute retention interval in the curve for the lowest degree of learning. As has been pointed out, this rise may be a remnant of the reminiscence effect

which Ward (45) has shown occurs maximally in his data at about 2
minutes. Suppose, then, the two series of associations are selected so that
the younger, which has just been learned, is equivalent by some convenient
criterion to an older series. After an interval of 2 minutes the younger
will have been augmented by the reminiscence effect. It will not have
fallen off more than the older series but will have gained instead. Thus,
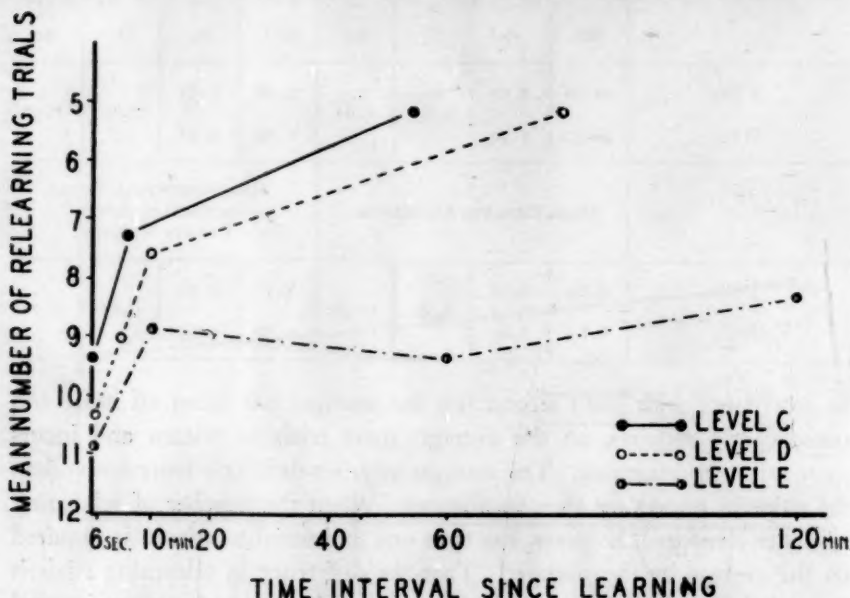
FIG. 14. CURVES ILLUSTRATING JOST'S FIRST LAW EXPANDED: FOR COMPARABLE POINTS
OF LEVELS C, D AND E, WHOSE EQUIVALENCE IS BASED ON
MEAN NUMBER OF SYLLABLES RECALLED

These curves show the number of relearning trials required at the comparable points
of Levels C, D and E to relearn to 12 correct anticipations on a single trial. The essential
equivalence of the points for each level has been demonstrated on the retention curves
based on syllables recalled at various intervals after three degrees of partial learning.
Time is in minutes except for the first retention interval, which represents the immediate
relearning and conforms to the usual time spacing between trials in the course of learning.
The points at the 6-second interval are based on 210 records for 15 subjects. The other
points are the mean of 30 records for 15 subjects.

at least one limit to Jost's second law is seen. It is probable that Jost's
first law has no such limiting situation, but a clearcut demonstration of
this cannot be made under the conditions of the present experiment.

Summary. The foregoing analysis has confirmed Jost's first law as it
was originally stated. The older association profits more by *a* new repe-
tition than the younger, no matter on what measure of retention the equiva-
lence is based. When optimal stability is provided by equating the

associations on initial recall, the extent of profit by the older association is a logarithmic function of the time since learning.

With one exception, Jost's first law is likewise confirmed in its expanded form. The older associations generally require fewer trials to relearn than the younger. When the equivalence is based on recall, the number of relearning trials for the comparable associations produce curves of a similar form. Tentatively, they may be regarded as curves of a single family with variable parameters which assume different values depending on the retention levels under consideration.

Jost's second law is confirmed for the single pair of associations available for such a check. Though exhibiting very low reliability in one instance, the younger associations are remembered less well after 20 minutes than the older. The typical negative acceleration of the retention curves suggests that at most of the comparable points examined, the retention curve is falling more rapidly for the younger association than for the older.

Evidence for a true limit to Jost's second law is found in the reminiscence effect. With adequate selection of comparable associations, the younger could be shown to fall off less in a given time than the older. However, when comparing equivalent associations at these low degrees of learning and retention, no limits to Jost's laws may be reliably demonstrated at the retention intervals selected for this study.

CHAPTER IV

FUNCTIONAL EQUIVALENCE AT COMPARABLE POINTS IN LEARNING AND FORGETTING

WHEN Jost explained his results in terms of an active process, age, he was fully in accord with the learning theory of his day. Forgetting was "a function of time" to Ebbinghaus (8). As late as 1914, Thorndike (44, *p. 4*) gives this statement of the law of disuse, "When a modifiable connection is not made between a situation and a response during a length of time, that connection's strength is decreased". These last years have seen a major advance in forgetting theory. McGeoch, in 1932 (26, *p. 369*) following a summary of the experimental work on oblivescence during sleep and waking,[1] and retroactive inhibition[2] under a variety of conditions, was able to conclude that:

"(1) This law (the law of disuse) is not a general law which it purports to be, because of the lack of correlation between disuse and forgetting.

"(2) In situations in which forgetting and disuse are highly correlated, the disuse cannot be alleged to be the necessary condition of the forgetting. Ascription of effectiveness to time violates the usage of science and is logically meaningless."

Essentially, Jost's laws with their implication of an active process in age are obsolete. In the foregoing chapters, time has been considered simply a frame of reference for the undefined process which causes the older associations to be stronger than the younger. However, before any more satisfactory statement of the laws is possible, it is necessary to suggest what this process may be. Only by a comparative analysis of the functional characteristics of the younger and older associations can evidence for this process be found.

Distribution of Errors as a Measure of Functional Equivalence. An obvious first choice for the study of functional equivalence is a comparative analysis of error distributions. For years discussion and evidence has been organized around the respective efficacy of primacy and recency positions

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[1] Greater oblivescence during waking than during sleep has been demonstrated experimentally by Dahl (7), Jenkins and Dallenbach (18), and others.

[2] Factors determining the amount of retroactive inhibition and particularly the similarity factor has been extensively investigated by Robinson (38), Whitely (47), Harden (13), Skaggs (43), and McGeoch (28).

in serial learning.[3] Raffel (36) has shown that the type of error distribution is a function of the method of measuring retention. Granting that this is so, there still remains the profitable analysis of error distributions under well-defined conditions.[4] Hull (15), in his discussion of conflicting psychologies of learning, has invoked conditioning principles to predict rote-learning phenomena and has anticipated the findings of Ward (45), Hovland (14), and Hull (16) with signal success.

Hull's approach is based essentially on the Lepley hypothesis (22, *p. 283*):

". . . we may have established, in our learned series, phases of excitation and of inhibition analogous to the two phases of the delayed reflex as demonstrated by Pavlov."

Hull (15, *p. 503*) postulates, somewhat more fully:

" The period of delay of trace conditioned reflexes possesses power to inhibit (temporarily) to a certain extent the functional strength of excitatory tendencies, the reactions of which would otherwise tend to take place during such a period."

According to this theory, the secondary inhibition [5] which develops in the course of learning prevents the ready memorization of the intervening syllables. Because of the greater number of remote excitatory bonds, inhibition occurs maximally in the middle of the rote-series and to a decreasing extent at either end. This conforms, roughly, to observed distribution of errors in learning such series.[6] Hull, among other associated ones, presents these additional postulates:

". . . Inhibitory tendencies in the early stages of weakening through lapse of time diminish more rapidly than do associated excitatory tendencies.

. . . The 'actual' strength of excitatory tendencies accumulated through repetitions is not influenced by the previous presence of superposed inhibitions of delay." (15, *p. 503*.)

With these he was able to predict results that he later confirmed experimentally, *i.e.*, that:

". . . the marked excess in difficulty of recalling the syllables in the late middle of rote series, so characteristic of the learning by massed practice, disappears entirely after a period of some twenty hours of no practice." (16, *p. 271*.)

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[3] The influence of primacy and recency on verbal learning was treated by Calkins (6) as early as 1894, and in the following years by Ebbinghaus, Robinson and Brown (41), Jenkins and Dallenbach (19), and others.

[4] An analysis of the error distributions for the course of original learning in the present experiment is presented in the dissertation on file in the Yale University Library.

[5] For the implications of this terminology see footnote 2, chapter I.

[6] An hypothesis to reconcile observed error distributions in learning and current theory is presented in the appendix of the dissertation on file in the Yale University Library.

The more rapid dissipation of the secondary inhibition than of the excitation is a process which is correlated with time and which, forthwith, must be considered a possible explanation of Jost's laws. According to conditioning principles, the greater the extent of this dissipation, the more readily the rote-series should be relearned. If then, two series of associations
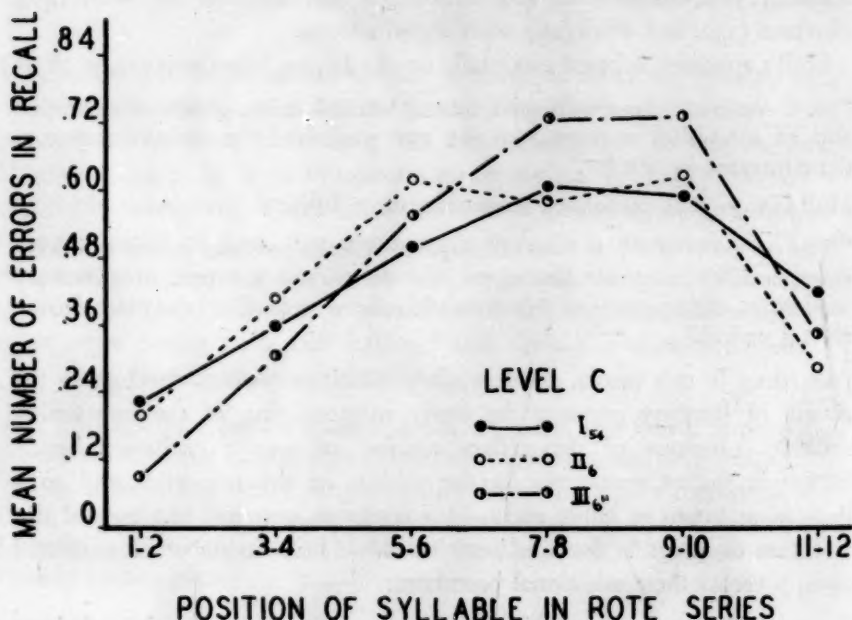
FIG. 15. DISTRIBUTIONS OF ERRORS IN RECALL ACCORDING TO SERIAL POSITIONS FOR THE POINTS ON LEVEL C, EQUATED ON MEAN NUMBER OF SYLLABLES RECALLED

The distributions of mean number of errors in recall according to serial position are presented for the three equivalent points of Level C. I_{54} and II_6 are interpolated points from the retention curves of recall after various intervals of time following 2 degrees of partial learning. Point III_6" represents the corresponding point in learning. Each point on the error curves for I_{54} and II_6 is a value for which it was necessary to interpolate between the error means for 2 adjacent points on the respective curves. The error means for each of these points was based on 30 records for 15 subjects. The observed mean errors for III_6" are based on 330 records for 15 subjects. Each point on these error distributions is the averaged result for pairs of serial positions.

are equated according to some retention measure such as number of syllables recalled, the older one, which is characterized by a greater lapse of time since learning, should exhibit greater dissipation of the secondary inhibition built up during learning. The older, consequently, should be relearned to a greater degree than the younger upon another single presentation of the material. Presumptive evidence for the extent of dissipation of the intralist inhibition may be found in error distributions. The older series of asso-

ciations should show a greater reduction of errors in the middle of the rote-series where, theoretically, the secondary inhibition was at a maximum. It remains to be demonstrated whether this prediction is borne out for the comparable associations of the present study.

Distribution of Errors in Recall for Comparable Points. The mean number of errors in recall for each pair of serial positions is presented in Figure 15 for the three comparable points, identified in Figure 9 as Level C. $III_{6''}$, the error distribution from the corresponding point in learning, exhibits an excess of errors in the middle of the series. There is a marked reduction in errors in the middle of the series for II_6, and for the even older associations of I_{54}. A more detailed comparison can be made when the reliability of the differences confirming Jost's first law are compared with the differences in mean errors revealed in the middle of the rote-series at syllables 7 and 8 in Figure 15:

Younger and Older Pairs of Points Level C	Critical Ratios of Differences in Increment on Recall II Confirming Jost's First Law	Difference in Mean of Errors in Recall at Serial Positions 7 and 8
I_{54} and II_6	2.40	0.02
II_6 and $III_{6''}$	2.60	0.14
I_{54} and $III_{6''}$	4.75	0.12

Of these three pairs of points the one showing the least difference between the mean errors in recall at serial positions 7 and 8 also shows the lowest critical ratio in the confirmation of Jost's first law. Other than this no very direct relationship is evident. In spite of the irregularity of the curve for errors in recall at retention interval II_6, Figure 15, there is a suggestion that the older associations exhibit more extensive dissipation of the secondary inhibition accumulated during learning.

With this suggestion in view the error distributions at recall for a considerably greater number of comparable points must be examined. Similar error distributions for Level D (see Figure 9 for identification) are presented in Figure 16. Again the older habits show considerable reduction of errors at the middle of the rote-series while the youngest habit, representing the corresponding point in learning, exhibits the usual excess of errors for the middle syllables. The relation between the critical ratios of the differences of profit on a new repetition, which confirm Jost's first law,

and the amount of dissipation of inhibition at serial positions 7 and 8 follow:

YOUNGER AND OLDER PAIRS OF POINTS LEVEL D	CRITICAL RATIOS OF DIFFERENCES IN INCREMENT ON RECALL II CONFIRMING JOST'S FIRST LAW	DIFFERENCE IN MEAN OF ERRORS IN RECALL AT SERIAL POSITIONS 7 AND 8
I_{80} and II_{10}	1.84	0.03
I_{80} and L	4.45	0.16
II_{10} and L	1.88	0.18

These comparisons exhibit the same confirming features and the same equivocal characteristics that were seen in the detailed analysis of Level C. When similar comparisons are made for Level E a more direct relationship is seen. In Figure 17 the distribution of errors in recall according to serial position is presented. Here four curves of error distribution are available for simultaneous comparison. It is evident that the younger the habit the greater is the mean number of errors in the middle of the list. The summary of the reliability of the differences confirming Jost's first law and the extent of the dissipation of the inhibition follows:

YOUNGER AND OLDER PAIRS OF POINTS LEVEL E	CRITICAL RATIOS OF DIFFERENCES IN INCREMENT ON RECALL II CONFIRMING JOST'S FIRST LAW	DIFFERENCE IN MEAN OF ERRORS IN RECALL AT SERIAL POSITIONS 7 AND 8
I_{120} and II_{80}	0.99	0.0
III_{10} and L	1.41	0.04
II_{80} and III_{10}	1.96	0.07
I_{120} and III_{10}	2.19	0.07
I_{120} and L	4.06	0.11
II_{80} and L	7.75	0.11

Here there appears a close correspondence between the amount of dissipation of secondary inhibition exhibited at serial positions 7 and 8 and the extent to which Jost's first law is confirmed.

When comparable points from all these series are considered together, the correlation between the magnitude of the critical ratios and the differences

in mean errors exhibited at the middle of the rote-series for the paired associations is 0.56 ± 0.14 (Rho).

On further examination of the error distributions in recall there appears a tendency for the maximum number of errors in recall to be displaced slightly to the right of the middle of the list in the case of the younger associations. This displacement is particularly noticeable in the young asso-

FIG. 16. DISTRIBUTIONS OF ERRORS IN RECALL ACCORDING TO SERIAL POSITIONS FOR THE POINTS ON LEVEL D, EQUATED ON MEAN NUMBER OF SYLLABLES RECALLED

The distributions of mean number of errors in recall according to serial position are presented for the 3 equivalent points of Level D. I_{80} is an interpolated point from the retention curve of recall following the highest degree of learning. II_{10} is an observed point and the remaining distribution is from the corresponding point in learning. Each point on the error curve for I_{80} is a value for which it was necessary to interpolate between the error means for 2 adjacent observed points. The error curves for each of the observed points are based on 30 records for 15 subjects with the exception of the corresponding point in learning, which is based on 330 records for 15 subjects. Each point on these error distributions is the averaged result for pairs of serial positions.

ciation series selected from the point in learning corresponding to the obtained retention values; Figures 15 and 16. In Figure 17 this displacement of the maximum occurs in both of the younger habits, L and III_{10}. It was shown in a preliminary analysis that the displacement of the maximum to the right is a characteristic of error distributions for low degrees of

learning. Here, then, it is evidence of the different degrees of original learning used as a basis for the study. While, as a functional characteristic, the displacement of the error maximum in the rote-series is a legitimate means of differentiating the younger and older associations; practically, it does not offer for the present experiment, sufficient range or stability for detailed study. The most consistent functional differences between the
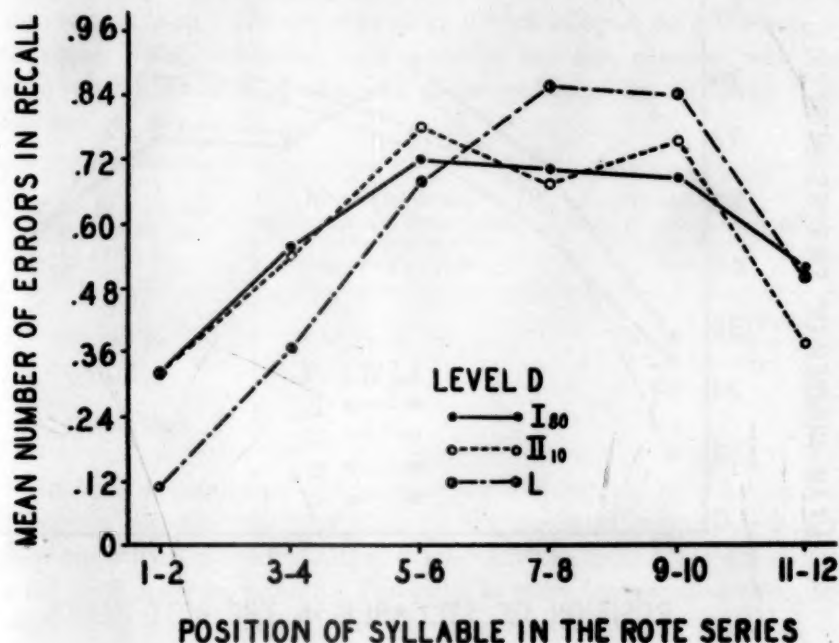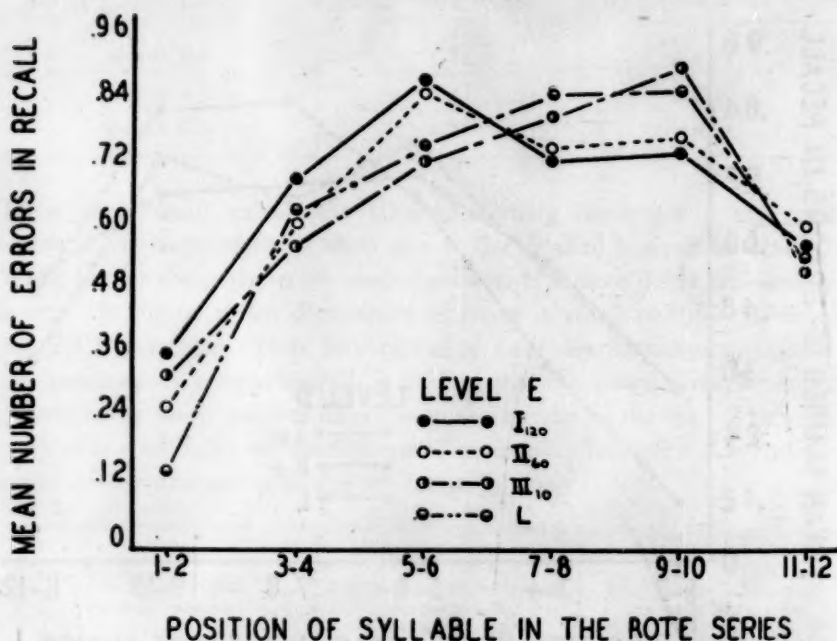

Fig. 17. Distributions of Errors in Recall According to Serial Positions for the Points on Level E, Equated on Mean Number of Syllables Recalled

The distributions of mean number of errors in recall according to serial position are presented for the four equivalent points of Level E. I_{120}, II_{60}, and III_{10} are observed points on the retention curves of recall after various intervals of time following three degrees of partial learning. The fourth point represents the corresponding point in learning. The error means for the first three points are based on 30 records for 15 subjects. The means for the points in learning are based on 330 records for 15 subjects. Each point on these error distributions is the averaged result for pairs of serial positions.

associations of different ages appear in the excess of mean errors at the middle of the rote-series for the younger associations.

Distribution of Errors in Relearning for Comparable Points. The expansion of Jost's law, positing the superiority of the older habit during the whole process of relearning, makes the examination of error distributions for the entire relearning pertinent. When the habits are equated on number of errors in relearning, the comparisons between the younger

and older should still show, according to conditioning principles, an excess of errors in the middle of the rote-series for the younger habits. In Figure 18 the error distributions for the three habits previously identified as Level A of Figure 7 is presented. According to expectations, the older habit shows the fewest errors at positions 7 and 8; the next youngest habit shows considerably more errors, but the results are somewhat equivocal since this habit exhibits slightly more errors in the middle of the series than the youngest habit. The extent to which the reliability of the differences in relearning trials, confirming Jost's expanded first law, coincides with the observed differences in mean errors in the middle of the rote-series is as follows:

Younger and Older Pairs of Points Level A	Reliability of the Differences in Relearning Trials Confirming Jost's Expanded First Law	Difference in Mean Relearning Errors at Serial Positon 7 and 8	
III$_{9^a}$ and II$_{49}$	0.46	1.8	Older habit shows an excess of errors
II$_{49}$ and I$_{129}$	1.12	7.0	
I$_{129}$ and III$_{9^a}$	1.86	8.8	

When the entire process of relearning is considered, the reliability of the differences between relearning trials for the compared associations is not great but the magnitudes are directly related to the mean error differences at the serial positions, 7 and 8. This yields to ready interpretation from the conditioning point of view. In relearning, more secondary inhibition is built up so the differences between the younger and older associations, which were fairly reliable at the first relearning trial, are now partially obscured in the subsequent learning.

In spite of the few minor contradictions and the occasional irregularities in the data, it appears that a relative reduction in the mean number of errors occurring in the middle of the rote-series in recall, and subsequently reflected in relearning errors, is a phenomena which progresses with the lapse of time. It probably is responsible for the differences between the older and younger habits, expressed in Jost's laws.

Anticipatory Displacements as a Measure of Functional Equivalence. Another functional characteristic, which might be discriminative at comparable points in learning and forgetting, is the number of anticipatory displacements in recall and relearning. Hull (16, *p. 261*) has shown that a significantly fewer number of anticipatory intrusions occur in recall 20.5

hours after learning than at the corresponding point in the course of original learning. However, when the mean number of anticipatory displacements in recall were tabulated [7] for the comparable points on the retention levels selected for this study, neither reliable differences nor consistent trends appeared. The relatively few total displacements available for study and the short retention intervals represented in the pairs of younger and older associations may account for the unfruitfulness of such an analysis.
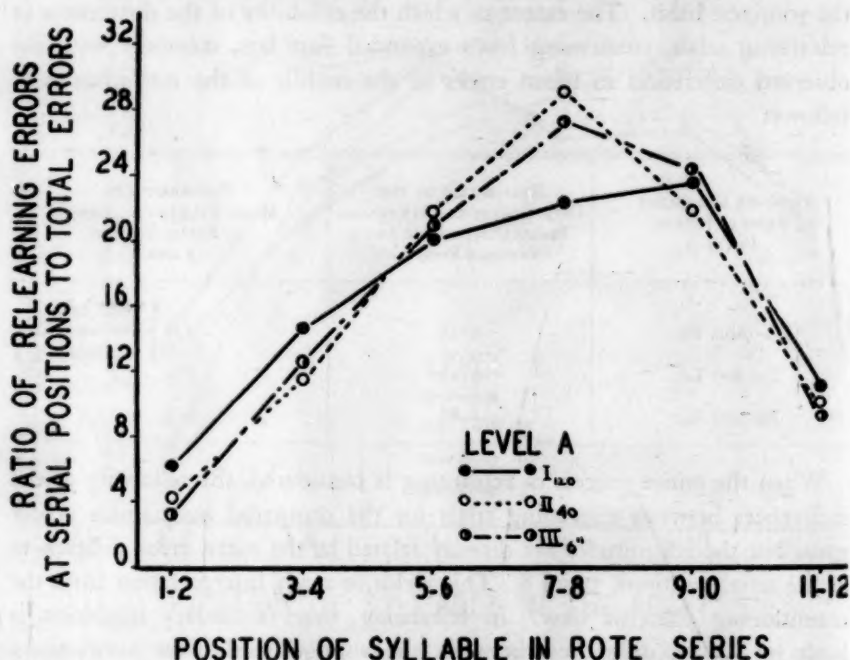
FIG. 18. DISTRIBUTION OF ERRORS IN RELEARNING ACCORDING TO SERIAL POSITIONS FOR THE POINTS ON LEVEL A, EQUATED ON MEAN ERRORS IN RELEARNING

The distributions of errors, in terms of ratio of relearning errors at each serial position to total errors for all syllable positions, is presented for the 3 points of Level A. The essential equivalence of the observed points I_{120} and II_{40} and the corresponding point from learning, III_{6}", has been shown in Figure VII. Each point on the error distributions for I_{120} and II_{40} was based on 30 records for 15 subjects, while each point for III_{6}" was based on 210 records for 15 subjects. Each point on these error distributions is the averaged result for pairs of serial positions.

Theoretical Interpretations. It is now evident that the most discriminative of the functional characteristics exhibited by the comparable younger and older associations of this study appears in the distribution of errors. There is a progressive decrease in the relative number of errors occurring in the middle of the rote-series for the older associations. In applying

[7] Details of this analysis are available in the dissertation on file in the Yale University Library.

conditioning principles to rote-learning Hull (15) has predicted just this result. No other current learning theory appears to possess postulates by which this effect could be anticipated or explained.

The recent attempt of the Gestalt psychologists to explain the relative reduction in errors by a process of progressive "organization of the traces", may eventually have merit. At its present stage as a "general" concept it has little predictive power. It is difficult to see what advantage this concept has over the idea of progressive perseveration or "setting in" after learning which was put forward by Müller and Pilzecker (32) in 1900. The chief difference lies in the particular emphasis of total organization in the former versus individual associative bonds in the latter. McGeoch (28), in showing that the interpolation of new material immediately after learning is no more detrimental to the retention than interpolation just before relearning, has cast doubt on all such contentions.

On a rather superficial level the association theorists can ascribe the more rapid relearning of the older habit to the advantage of a higher degree of original learning. According to the limited synaptic-resistance conception, neural bonds, which had once been established, should be easier to reëstablish: material which had been learned to high degree of integration should later, after forgetting, be relearned more rapidly than material less well learned. So far so good, but if different degrees of learning are under consideration should there not be different degrees of learning within the material? McGeoch (24) has pointed out the various conditions which may influence the degree of learning. A major one, of course, in rote-learning is the number of correct recitations a given syllable has received in learning. When recitation rather than simple presentation is considered to be the major strengthening influence as a given rote-series is learned, then, markedly different degrees of learning are represented within the list. The early and late items are well over-learned due to more frequent repetitions, while the middle syllables exhibit a low degree of learning. McGeoch has shown that lower degrees of learning are more susceptible than the higher degrees of learning to the disintegrating effects of interpolated learning or activity. Upon applying this finding to a given learned series, the middle syllables, representing a lower degree of learning, should be inhibited and forgotten at a faster rate than the overlearned syllables at either end of the series. At a later recall, then, a proportionally greater number of errors should occur for the poorly learned syllables in the middle of the series. The observed facts are just the opposite of this expectation. Actually there are proportionally fewer errors in the middle of the series.

Hull (15), postulates that the real strength of the associative bonds, his

excitatory tendencies, as accumulated through repetitions, is not influenced by the previous presence of superimposed inhibitions of delay. Hence, these middle syllables, where the inhibition during learning develops most markedly, are still being learned to some degree even though not recited. In the time interval after learning, the inhibition dissipates rapidly. These middle syllables appear as learned to a degree out of all proportion to the number of recitations during the original learning. Thus, Hull has avoided the emphasis of the special strengthening influence of repeating the syllables, which, in view of recent experimental results, is certain to embarrass the orthodox association theorists.

It appears that close approximations to observed facts in an analysis of Jost's laws can be made by the application of conditioning principles to this type of material. The limit to Jost's second law provided by Ward's reminiscence effect makes Jost's second law, as a general principle, obsolete. However, a reformulation of Jost's first law from this conditioning point of view seems possible:

Of two series of associations which are overtly remembered to the same degree, the one exhibiting the most extensive dissipation of intralist inhibition will profit more on a new repetition.

Such a restatement of Jost's first law makes further analysis imperative. Although suggestions have been made in the course of the discussion, the data of the present study do not provide any direct answer to the controversial questions of what the fundamental nature of this inhibitory process is, or how it operates to produce differential relearning in the older and younger associations. Further experimentation will be necessary to solve these persistent problems.

CHAPTER V

THE accredited position of Jost's laws in the body of psychological knowledge is as much due to indirect evidence as to the experimental results leading to their formulation. This experiment is an attempt to evaluate Jost's laws only as they apply to series of associations which have received various amounts of original learning and have been forgotten to levels of equivalence with younger associations. The comparable series of associations for this study were derived from retention curves following three degrees of partial learning. Fifteen subjects learned standard 12-unit nonsense-syllable lists by the spelling-anticipation method to three criteria, 12 correct anticipations on a single trial, 7 and 4.5 correct anticipations on two successive trials, respectively. Relearning for each of these degrees of learning occurred at 6 seconds, 10, 20, 40, and 60 minutes, and, for the highest degree, at 2 and 24 hours in addition.

Nine series of three or more equivalent points for an analysis of Jost's laws were obtained by cutting across the retention curves based on errors in relearning, recall I, and relearning trials at various levels. The results and conclusions from the study of these points follow:

1. Whether the associations are equated on errors in relearning, recall I or trials to relearn, the older habit shows a larger learning increment after a single relearning trial, thus confirming Jost's first law as he stated it.

2. When the comparable points are initially equated, as on recall I, the amount of profit on new repetition tends to increase logarithmically, according to the time since learning:

$$y = K \log t + c$$

3. The customary expansion of Jost's first law appears justified for, with but one exception, the older associations require fewer trials to relearn than the younger.

4. When the equivalence is based on initial recall the relearning trials required at the comparable points yield curves, similar enough in form to be regarded as belonging to a single family with variable parameters, which assume different values depending on the retention levels under consideration.

5. Jost's second law is confirmed for the points available for such a

check in the present study. Theoretical limits to the second law are evident in the reminiscence effect demonstrated experimentally by Ward.

6. The functional characteristic most discriminative of equivalent older and younger associations is the distribution of errors, both in recall and in relearning, for the comparable points. The younger habits display an excess of errors in the middle of the rote-series.

7. Since this result seems more in accord with a conditioned response interpretation of rote-learning than any other prominent learning theory, it justifies a tentative restatement of Jost's law according to conditioning principles:

Of two series of associations which are overtly remembered to the same degree, the one exhibiting the most extensive dissipation of intralist inhibition will profit more on a new repetition.

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APPENDIX

ADDITIONAL DETAILS OF EXPERIMENTAL PROCEDURE

CRITERIA FOR THE CONSTRUCTION OF THE NONSENSE-SYLLABLE LISTS OF THE PRESENT STUDY

More than 36 nonsense-syllable lists were prepared for use in the present study. These lists were constructed according to the following rules: [1]

1. All syllables have Glaze association values of not more than 53.33 per cent.

2. No syllable with Y as a letter has been used.

3. No vowel is repeated in any consecutive 4 syllables, except at the beginning and end of the list, *i.e.*, a vowel which occurs in the last 3 units of a list may be used in the first 3 units of the same list. The vowel last used in a list cannot, however, be the vowel first used in the same list.

4. No 4 consecutive syllables have any letter, either vowel *or* consonant in common, and no letter appears twice as an initial consonant or twice as a final consonant in a list.

5. No 2 syllables within a list contain 2 letters, either vowels or consonants, in common.

6. Alphabetical progressions, *e.g.*, KEM, LON, are avoided as far as possible.

The nonsense-syllable lists are reproduced on the following pages. The mean association value of each is indicated.

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[1] This modification of G. E. Müller's rules was partially suggested by the work of A. W. Melton. Some of the modifications were necessary in order to obtain an adequate number of lists of the requisite association value.

LISTS OF 12 NONSENSE-SYLLABLES

List 1	List 2	List 3	List 4	List 5	List 6	List 7	List 8
MOX	KUM	VEH	JIC	GAW	PUK	JAT	SEJ
KAQ	NEQ	QAM	KUX	RUQ	ZAC	FUQ	XIP
CEZ	BIW	JUC	HES	KEZ	NOL	GIW	RUC
JID	JOZ	SOZ	ZAN	JOF	XIF	MOH	QOB
BUH	VUC	PEF	RIW	NIH	BUJ	ZEJ	GEZ
VAP	MAF	TIW	MOG	XAV	QAP	DUP	JIH
TEW	XIN	GUK	BEP	QET	WEZ	NAX	CAX
QIN	TEK	NOQ	QUJ	FUP	CIH	KIB	VUD
XUK	DUH	HAJ	XIZ	WOB	VUT	QEG	TOQ
SOJ	WOS	CES	TOH	MIJ	DOQ	WUZ	WEM
ZIT	QIJ	XUR	DAK	VEC	KAM	VOR	ZIL
GEV	GEB	MIP	PUV	ZUN	GEX	XID	KAG
28.33	29.44	27.22	28.33	27.22	27.22	26.67	27.78

List 9	List 10	List 11	List 12	List 13	List 14	List 15	List 16
VAW	VOG	SUQ	CEK	CIW	PAF	ZON	MIG
DUF	FIK	ZIW	PUH	PAH	ZIS	VUK	ZUC
XEG	WUH	KEH	VAD	NUV	NUR	BIH	PEJ
KOH	PEZ	XOB	ROJ	QOM	VEK	PEQ	XOT
WIQ	MAQ	NAC	ZEX	DIJ	GOQ	DAJ	NAQ
ZUB	JIV	VUF	QUW	KAX	TAJ	WUC	KIZ
MEV	KON	WEP	KAL	GEP	BIP	KIF	WUS
GAK	XUD	RIK	TIV	VOB	XEZ	HEG	CEB
SIT	GEF	QON	HEF	HUQ	CUG	QOP	GAH
CUX	BAI	DUZ	NUB	ZIK	JOM	RUZ	LIX
QOD	QIW	LAJ	WAZ	TEF	QID	NIW	QUP
HEZ	ZUM	FEX	DIQ	XOL	LEH	XEB	VEF
26.11	26.67	27.78	27.22	27.22	28.67	27.78	27.22

LISTS OF 12 NONSENSE-SYLLABLES—*Continued*

List 17	List 18	List 19	List 20	List 21	List 22	List 23	List 24
QUT	CEF	ZAS	GOK	RUW	MEC	NIJ	JOD
BEX	HUW	RUH	VUN	VOH	GIX	KUQ	QIM
KOJ	JOQ	VIB	JEZ	KAZ	TUD	VOC	WEG
VIG	PIB	KOG	WIB	JEQ	NOJ	XEH	ZUL
ZUR	GAX	XAD	FAQ	PID	WEF	TIS	KAJ
MEF	KEV	PEM	XOM	BOF	QIB	QAD	BIV
WOQ	MUN	FIW	DEH	XUM	KUG	MUW	SEH
TIH	TOC	COJ	KUW	CEG	VOP	JEB	XUC
XAP	LIJ	NUX	QIG	WIJ	ZEL	ROF	GAF
JEC	ZEP	HAQ	LOJ	FAP	FIH	CIK	LIW
FUW	NAH	TIZ	TEV	QOT	XAT	GUX	DEQ
NIZ	XOW	JEK	HUC	LEB	PUQ	ZAL	NUK
27.22	27.78	28.33	27.78	26.67	26.67	27.78	27.22

List 25	List 26	List 27	List 28	List 29	List 30	List 31	List 32
SUH	XAL	NEF	ZOT	GUC	NID	BEH	GOX
KEB	TIJ	TOV	LUB	KEM	QEJ	KUV	JEP
NAW	GUD	LIH	WAH	BIX	ZUK	NIR	VID
GIZ	MOF	BAZ	QEM	POH	XOR	WOJ	QUK
VUM	HEB	QUN	XOJ	LUD	PIV	ZAM	COH
FEP	RIX	GEK	CIZ	ZEG	BEW	QEP	ZAT
CAJ	JUQ	DIW	RUV	VIW	JUF	GUB	PIW
ZOR	ZOP	SAJ	KEF	NOF	GAC	SIW	MUB
WUT	FEC	MUX	POQ	XAK	KOQ	HOZ	FOJ
LEQ	VAK	HEQ	DAX	SEB	MIB	DAQ	XEC
XAF	SIH	ZIC	JIS	JIZ	WUP	TEG	NIQ
JIK	PUW	WAP	NUW	QOV	FEH	JUX	TUV
26.11	27.78	27.78	26.67	26.67	26.67	27.22	26.67

LISTS OF 12 NONSENSE-SYLLABLES—*Continued*

Practice List P1	Practice List P2	Practice List P3	Practice List P4	Practice List P5	Practice List P6	Practice List P7	Practice List P8
GEC	JUH	MIV	TAH	NOK	BUQ	ZIN	FAJ
JIW	QAZ	CEX	MEQ	ZUG	JEX	CUW	BUP
XUB	WOG	FOQ	GOC	LER	GID	QOK	REZ
TOZ	CIB	GUW	LIJ	QAS	LAH	VAF	DIH
CEV	SUX	KAH	RUX	XIW	FOV	BIJ	QOS
PAQ	KED	LEJ	QEN	KUD	WUK	MEP	XUL
RUK	POV	DIB	POB	TEZ	MEZ	XUG	JEG
ZIF	LIJ	NUZ	WIK	GOC	CIJ	NAL	NIV
BEJ	ZUS	VOF	XAG	MIF	QAR	FOH	KOR
VOM	GAQ	QEK	NEH	WUB	XUN	WEQ	ZAB
KAR	XEF	XAR	SIF	DAH	TEB	JUZ	MUQ
FUH	MIC	ZUN	VUW	VEP	ZOS	DAC	WIX
25.56	27.78	27.78	29.44	29.44	28.33	29.44	29.44

INSTRUCTIONS TO THE SUBJECT

In this experiment you will learn lists of nonsense-syllables. A nonsense-syllable is a three-letter word—a consonant, a vowel, and a consonant,—which has no meaning. These syllables will be presented on this revolving drum and will appear in this window in the screen. You will learn by spelling each syllable and by anticipating each syllable of the list.

This symbol indicates that the first syllable is about to appear. Always spell the syllables, do not pronounce them. The first time the list of syllables is presented you will watch each syllable carefully and concentrate on each as long as it is exposed. However, beginning with the second presentation you will begin anticipating—that is, spelling out the expected syllable just before the drum turns the syllable into the aperture. Thus, when the symbol appears, try to spell out the first syllable. When the second syllable is in the window, try to anticipate the third syllable, etc. Always spell the letters out loud in a clear voice. If you can't name all the letters of an anticipated syllable, then spell as many as possible and always anticipate as many syllables in the list as you can.

It is, of course, necessry to spell the anticipated syllable in the period just before it appears. Keep in time with the drum. The spelling must be completed before the drum turns. Spend all of the exposure period of each syllable, studying that syllable or attempting to anticipate, *i.e.,* spelling out the syllable immediately to follow. Continue this learning until the experimenter stops the trials.

Try to anticipate correctly but do not be disturbed if a correct anticipation on one trial isn't always continued. Keep on trying. Please don't ask any questions concerning the aim of the experiment until all of the experimental sessions have been completed. In addition, it is essential that you do not think about the experiment at all, either in the second experiment or between experimental sessions. Don't talk to anyone about what you are doing here. If something connected with the experiment comes to mind, quickly think of something else. Do your best but if it seems difficult do not worry or concoct schemes to speed up your own work. The important thing is to follow directions. Have you any questions about what we are going to do? Does the method seem clear?